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CULTURAL APPROACH TO COLONIAL AGRICULTURAL DEVELOPMENT

The introduction of a new crop or a new farming method sets up a chain of events which affects to a greater or lesser degree the cultural pattern of the life of a people. It is only by an understanding of the cultural characteristics of a people that we can translate successfully our knowledge for their benefit — agricultural policies must be sound culturally as well as technically if the results are to be satisfactory in terms of the welfare of the people concerned. The acceptance of innovations from another culture without their full cultural implications may be attended with disastrous consequences, as in the case of the adoption of the benefits of medical science without control of family or intensified agriculture; veterinary science without improved animal husbandry; or the adoption of the plough without mixed farming. In such cases it is generally the soil which suffers first, and ultimately, the people.

Culture in the anthropological sense covers every aspect of the life of a people; it is described as being a closely integrated and interdependent whole which is made up of the sum total of the practices, skills, arts, crafts, traditions, customs, habits, beliefs, superstitions and rituals which taken together constitute a way of life. Because of this essential unity of culture, particularly pronounced in primitive societies, agricultural extension workers cannot confine themselves successfully to a narrow technical interpretation of their functions but must base their policies and programmes on the total life of the people. They must get down to what the Americans so aptly call the "grass roots".

Whilst culture is of necessity conservative and resistant to change, it has considerable absorptive powers and is never static in a changing world; it is continually adapting itself to external influences — educational, social, economic and psychic. If this were not the case there would be no basis for extension work and no justification for Departments of Agriculture. Contacts between culturally diverse people inevitably bring about changes which may be slow and evolutionary or rapid and revolutionary.

Departments of Agriculture are concerned as a rule with the slowness of the adoption of agricultural improvements, in relation to the rapidity of change brought about by disruptive forces outside their control. The slowness of desirable change may be a measure of the ineptitude of Departments as teachers, of unsuitability of the teaching material, or cultural factors may be involved which make change difficult. A new technique for carrying out a new function, such as a lorry for long distance travel, is generally easier to introduce than a new technique for performing an old traditional function, such as a tractor plough for cultivation. Cotton regulations introduced to Uganda with that crop are accepted by the people, but not interference with the cultivation of their traditional banana.

Every society is unique in that it is the product of its own history and environment. A study of history together with cultural anthropology is therefore essential to a full understanding of the facts revealed by the primary agricultural survey which must be the starting point in agricultural development. This is particularly true in primitive subsistence societies where farming is essentially a tradition rather than a business. At a later stage in agricultural development, when the extension phase is reached, a Department of Agriculture aware of the cultural factors involved will know not only the technical answers to problems, but also how those answers can be geared-in to the life of the people. It is for this reason that it is important for subordinate staffs in Departments, who make the final contacts with the people in extension, to be locally recruited and locally trained as far as possible. The significance of a knowledge of the local language must also influence staff postings in all field appointments ; a factor notoriously overlooked in most departmental administrations.

It has been said that the basic needs of human beings — physical, social and psychic — are similar : peoples differ mainly in the manner in which they satisfy these needs. Differences reveal themselves in the complexity of the technologies (skills, arts and crafts), and in the customs, institutions and beliefs of a people.

Basic factors in technology are shown by the types of cutting tools used, by the methods of food acquisition, and by the methods of transportation.

Social customs and institutions concern human relationships, the relationship between man and man, whilst the psychic aspects of culture are shown by the beliefs, rituals, and superstitions, which govern the relationships of man with the supernatural (including the anthropologist's " magical aspects of agriculture ").

Primitive cultures generally have simple techniques and self-sufficient ways of life, combined with complicated social customs and rituals. Advanced cultures, by contrast, have complicated techniques, highly specialised dependent ways of life, with relatively simple customs and rituals. An appreciation of these differences is of great importance to those charged with responsibility for the development of so-called " backward " peoples. Some of the main differences are compared in greater detail below :

Primitive Cultures	Complex Cultures
Essentially rural ; all men farm.	Largely urban ; only one man in ten, or more, farms.
Self-sufficient ways of life : the habits of the individual tend to be the customs of the community.	Highly specialised, with maximum sub-division of labour and services.
Techniques simple and manual.	Techniques complicated and mechanised.
Subsistence economy ; food surplus bartered ; farming a custom. Profit motive weak or non-existent.	Cash economy ; food grown for profit ; farming a business. Profit motive strong.
Wealth judged by numbers of wives and livestock.	Wealth judged by bank balance.
Familistic ; society closely integrated tribally.	Individualistic ; society loosely articulated nationally.
Consanguinal family ties provide social security.	Family ties conjugal ; state provides social security.
Initiation ceremonies prepare for life.	Formal education in schools and universities.

Primitive Cultures	Complex Cultures
Tribute in kind is paid to family head to maintain position and extend hospitality.	Taxes in cash are paid to state and local government bodies for administration and social services.
Leaders hereditary.	Leaders elected.
Past and present regarded as important.	Present and future important.
Ancestor worship with complicated ritual in pagan societies.	Christianity with simple religious ritual.
Ancestors and family heads custodians of tradition.	Church and State custodians of tradition.
Life is precarious, birth rate high, death rate high.	Life more stable (?), birth rate low, death rate low.
Margin of subsistence and standards of living low.	High.
Way of life based upon tradition and superstition, resistant to change.	Way of life based upon application of science and economics, adaptable.
Tempo of life based upon seasons.	Based on the clock.
Communications poor and slow.	Communications highly developed and swift.
Labour relatively abundant and largely discounted as factor in production.	Labour most expensive item in production.
Inherent soil fertility and weather significant factors in production associated with elaborate fertility ritual.	Inherent fertility and weather less significant by application of science and specialised production.
Land tribally owned.	Land privately owned.

Everywhere primitive societies are disintegrating under the impact of economic development, education, and the general effects of culture contacts. These changes are imposing a strain upon traditional farming practices resulting in the loss of soil fertility and the physical removal of the soil by accelerated erosion. One of the biggest problems facing Colonial Governments is to teach farming people how to adjust their ways of life and methods of farming at a pace commensurate with the other changes going on around them. It is for this purpose that Departments of Agriculture have been brought into being, not as luxuries, as some urban-minded administrators are inclined to imagine, but as necessities. The end-point is not the furtherance of science for its own sake, not directly an increase in the cash return from agriculture, but the application of science to a study of the problems involved — by survey, research, and experimentation — leading to the successful extension of the results so obtained to improve and stabilise the ways of life of the people. The degree of accelerated soil erosion in a territory, coupled with the average level of living of the people, can generally be taken as an index of the success or failure of a Department in its primary function. Successful extension is not a matter of chance, it is a reward to a Department adequately staffed and directed with extension as the main objective.

SUMMARY

1. The "culture" of a people is a closely integrated interdependent whole made up of the practices, skills, arts, crafts, traditions, customs, habits, beliefs, superstitions and rituals which taken together constitute a way of life.

2. The introduction of a new farming practice affects to a greater or lesser extent the cultural pattern of a people. The acceptance of an innovation from another culture without the full implications may have disastrous consequences, as the acceptance of a plough without mixed farming, or the benefits of veterinary science without animal husbandry. A knowledge of the culture of a people is essential to ensure that agricultural policies are sound culturally as well as technically.

3. Culture is resistent to change but has considerable absorptive powers; it is never static. Changes are brought about by contact with other cultures as a result of political influences, education, economics, and new technologies. Such changes may be slow and evolution-

ary, or rapid and revolutionary. Culture change is the essence of agricultural extension.

4. Basic human needs, physical, social and psychic, are similar: people differ mainly in their manner of satisfying those needs. Primitive cultures have simple techniques and self-sufficient ways of life, combined with complicated social customs and rituals. Advanced cultures, by contrast, have complicated techniques, highly specialised ways of life, with relatively simple customs and rituals.

5. Departments of Agriculture have been elaborated as integral parts of Colonial Governments, as necessities not luxuries, charged with the function of teaching rural people how to adjust their techniques and ways of life sufficiently quickly to keep pace with the changes going on everywhere around them in an ever-changing, ever-shrinking world. To fulfil this function, Departments of Agriculture must be adequately staffed and directed with extension as their main objective.

C. W. L.

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NOTE ON A SIMPLE METHOD OF PLANT PROPAGATION BY CUTTINGS

Cuttings of a number of plants have been established without any special propagator for humidity control, by the use of the following simple technique: —

Before being set out in beds, the cuttings are dipped (except for the parts to be inserted in the ground) in liquid paraffin wax of low melting-point. This can be done conveniently in a wide boiling-tube, or in the case of stout cuttings by applying the molten wax with a camel-hair brush. A greater percentage of success, and stronger plants, can be obtained by the use of a proprietary hormone preparation in conjunction with the above technique. With the white variety of Bourgainvillea, the following results were obtained:

Control, no treatment ..	22%
Paraffin wax treatment only	67%
Paraffin wax and hormone (powder)	100%

Stem cuttings of breadfruit, which is generally propagated by the somewhat tedious method of root-cuttings, have been successfully established by the paraffin wax plus hormone powder technique described above.

Evans (Ann. Report Sugar-cane Research Station Mauritius for 1947) described a similar method for propagation of *Eupatorium pallescens,* but found no improvement from the use of various growth hormones.

G.C.S.

THE PESTS OF JUNIPER IN BERMUDA

By

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INTRODUCTION

The Bermuda cedar, *Juniperus bermudiana* L., is the dominant tree, forming almost a pure stand, covering the whole of the Bermudas or Somer's Islands which together comprise an archipelago of aeolian limestone, 20 miles long by half a mile wide. The total area is some 13,440 acres in extent. This consociation of cedar has been described by Beard (2) as a sub-tropical maritime woodland formation.

In view of their geographical position, 568 nautical miles off Cape Hatteras on the North American coast, the Islands have for long been an important Naval base. They have in addition developed a flourishing tourist trade, valued conservatively at £4 million sterling per annum. A considerable proportion of the land area as a result has been cleared of trees and is occupied by bases, hotels and private residences as is shown in Table I. As may be seen, there are no forest reserves or " Crown Land ". Only a small proportion of the total area, about 300 acres, provides from two to three harvests a year of vegetables for the local market, and 1,000 acres consists of rough grazing *Stenotaphrum secundatum* (Walt.) Kuntze.

Table I. Summary of Land Tenure in Bermuda, 1947

Land-holder	Area in Acres
British	
Naval and Military	919
Corporate Bodies	1,371
Private	8,085
Alien	
American Bases (leased)	691
American Bases (reclaimed land)	1,120
American Subjects	1,177
Portuguese Subjects	77
Total	13,440

According to Masters (18), the Bermuda cedar is closely related to, but distinct from red cedar, *J. virginiana* L. It is a more densely branched tree (Fig 1) with adult leaves twice the length of the latter, and with globose fruit containing 2 - 3 seeds instead of one. Flowering begins in February, with pollen anthesis reaching a peak by the second week in March and terminating in April (13). The fruit is ripe during September and October. Most of the vegetative growth takes place during the warmer months of the year. In height, it may reach 40 - 50 feet, with a girth up to 9 - 12 feet, and is equally at home on the dry limestone hills as in the brackish marshes.

The cedar is highly prized by Bermudians, not only for its usefulness as a wind-break, but for the tree's long association with the history of the Colony. Its timber furnished the ships employed in the Island's carrying trade in the Eighteenth century, as well as providing a durable wood for use as beams, rafters, wall-plates, floors and window-sills in the construction of their limestone houses.

The tree is short boled and of small size in the log. The wood is generally very knotty as a result of the branching habit of the tree, and has been found too irregular in the grain to be of any use as pencil slats. Tests conducted by the Forest Products Research Laboratory, Princes Risborough, in 1938, showed resistance to cutting to be about 14 per cent higher than slats of Florida cedar, *J. virginiana*, and approximately equal to that of Kenya cedar, *J. procera*. When tested as pit props, the wood was found to be brittle and to break suddenly without warning, a serious disadvantage for mining timber. The wood, however, remains in great demand locally, for the manufacture of furniture and souvenirs for sale to visitors.

Although greatly venerated, the junipers have been entirely neglected from a sylvicultural viewpoint. The trees have been allowed to spring up naturally with little attempt at reafforestation, thinning or pruning. The value of the latter operations was shown in 1938 when a Government Forest Gang was formed. Although World War II curtailed activities, the advantages of this treatment were demonstrated by the improved condition of the trees (Fig. 3).

So heavy was the demand for local timber by the early Colonists, that legislation was soon enacted, aimed at the prevention of further destruction of cedars. Dill (8) lists sixteen Acts passed during the period 1693–1878 by the Bermuda House of Assembly, aimed at indiscriminate felling. No laws however were passed to enforce replanting of denuded areas.

This resulted in a negative or *laissez faire* attitude towards the development of existing stands.

The depletion of cedars for use as fuel for homes and lime kilns became so serious that in 1831, the tread-wheel was held as a threat to fuel cutters who sold cedar without permission. During this period of scarcity, an attempt was made to encourage the planting of young trees by the then Governor, Sir William Reed. A small booklet was published by Simms (26) in which setting out young trees under three feet in height was recommended in October or during February to April. With the substitution of local limestone and imported lumber for house construction in the Nineteenth and Twentieth centuries, together with the use of kerosene and electricity for fuel, the cedars were left to grow unchecked. Today, there are more trees in the Islands than there were a century ago.

Little evidence of natural regeneration can be found in the present stands, but cultivated fields when abandoned to grass, are rapidly colonised by seedlings. In this connection, Baker (1) has stated he found little natural regeneration or young trees of *Juniperus procera* growing near parent ones in Kenya, but found them abundant under *Olea chrysophylla*, where pigeons roost after feeding on the berries. Troup (28) also refers to the dissemination of *J. macropoda* in Baluchistan by birds known as juniper eaters. In Bermuda, the passage of the seed through birds, although it occurs, is not essential to ensure germination if the berries are fermented before planting. Groves (14) found the maintenance of moisture to be very important for successful seed germination of Bermuda cedar. This may be the explanation why seedlings of the latter are commonly seen springing up under hedge-rows and other sheltered places where soil moisture is most likely to be retained.

The population of Bermuda is dense, with over 2,000 persons per square mile. Lack of protection, due to the effects of man and his domestic animals on the local vegetation, is one of the main factors retarding natural regeneration. Neglect to thin and prune existing stands has produced over-crowded conditions with much dead wood providing avenues of entry for wood borers, *Leptostylus praemorsus* F. and dry-wood termites, *Kalotermes* spp. As a result, fully one-third of the trees are prematurely hollow.

Bermudians for long have regarded their native tree as one of the Island's oldest inhabitants, a hardy survivor of the elements and immune to the ravages of pests and diseases. At first sight, this belief appears well founded. The tree is a xerophyte, ideally adapted to the dry, porous soil and the windy climate, existing even in the barest limestone rock and in the most exposed situations. However like many other components of insular floras, the tree has not been observed to be able to stand up to competition from introduced species. Two notable intruders which have developed rapidly at the expense of the local junipers during the past century are the fiddlewood, *Citharexylum spinosum* L., and the allspice, *Pimenta officinalis* Lindl. Both these trees have seeds disseminated by birds. Wherever they have become established they have crowded out the cedars.

Up to the beginning of the Twentieth century, the Bermuda cedar was singularly free from pests. This was a matter for comment by Verrill (29), who remarked in 1902, "The native cedar appears to be very little affected by insects. A pale Geometrid larva was observed spinning down from its branches in April but not in large numbers." The larva in question was later identified as *Thamnonoma ochrifascia* Warren *(Alcis verrillata* Dyar). The only other record of insect injury was a reference to hollow cedar trees by Strachy in the early Seventeenth century. His remarks are quoted by Lefroy (16) and may refer to damage by dry-wood termites, *Kalotermes* spp.

The apparent immunity of the Bermuda cedar to insect injury was undoubtedly due to the Islands geographical isolation. This advantage has been largely offset during the present century through the great increase in travel by sea and air, which brings some 80,000 visitors annually, together with importations of fruit, vegetables and nursery stock. The latter have been especially heavy in connection with the development of hotel gardens and private estates, and have provided means of entry of several serious pests (36).

The present check list of spiders, mites and insects recorded on the Bermuda cedar amounts to 47 species (Table II.), and is based on the investigations of Ogilvie (21), Cunningham (6, 7), Russell (25), Parker (23), Thompson (27) and the writer (30 - 40). Of these, 7 species cause serious injury, either directly or indirectly, to the foliage. They are in order of importance, the oyster shell scale, *Lepidosaphes newsteadi* Sulc., the juniper scale, *Carulaspis visci* Schr., the juniper aphid, *Cinara juniperi* De Geer, the juniper midge, *Contarinia juniperina* Felt, the spruce mite, *Paratetranychus ununguis* Jac., the cedar hopper, *Ormenis infuscata* Stal., and the black cedar scale, *Acutaspis perseae* Comstock. All are restricted to juniper in Bermuda, and with the exception of *Ormenis infuscata*, have been recorded within the past 17 years.

TABLE II

Check List of Spiders, Mites and Insects Recorded on the Bermuda Cedar up to April, 1947

SPIDERS

Argiopidae : *Cyclosa* sp.
Dictynidae : *Dictyna ? cambridgei* G. & I.
} Predaceous.

MITES

Cheyletidae : *Cheyletus* sp., predaceous on mites.

Eriophyidae : *Eriophyes* sp., in galls on twigs.

Gamasidae : Various undetermined species.

Laelaptidae : *Amblyseius* sp., predaceous.

Oribatulidae : *Eporibatula* sp., a scavenger.

Lucoppia sp.

? *Micreremus* sp.

Scapheremaeus sp.

Tetranychidae : *Paratetranychus ununguis* Jacobi, a serious pest of foliage.

ISOPTERA

Cryptotermes cavifrons Banks
Kalotermes approximatus Snyder
Kalotermes snyderi Light.
} Destroy heart wood

CORRODENTIA

Hyperetes guestfalicus Klb.
Lepidilla sp.
Psocidus sp.
} Harmless scavengers

COLEOPTERA

Anthonomus juniperinus Sanborn, on foliage.

Carpophilus dimidiatus Fabr., on fallen berries.

Leptostylus praemorsus F., bark borer.

Oeme linearis Harris, bark borer.

RHYNCHOTA — HETEROPTERA

Banasa euchlora Stal., on berries and foliage.

Lygus sp., on foliage.

RHYNCHOTA — HOMOPTERA

Acutaspis perseae Comstock, occasionally severe on foliage.

Carulaspis visci Schr., serious infestation on foliage.

Cicada bermudiana Verrill, nymphs feed on roots.

Cinara juniperi De Geer, serious on twigs.

Deltocephalus sp., on foliage.

Lepidosaphes newsteadi Sulc., severe injury to foliage.

Ormenis infuscata Stal., may cause defoliation.

Orthezia insignis Browne, on foliage.

Pseudococcus sp., on foliage.

NEUROPTERA

Chrysopa rufilabris Burm., predator of *Ormenis*.

THYSANOPTERA

Aleurodothrips fasciapennis Frankl., predaceous on foliage.

LEPIDOPTERA — HETEROCERA

Thamnonoma ochrifascia Warren, on foliage

DIPTERA

Allograpta obliqua Say, predator of *Cinara*.

Contarinia juniperina Felt, causes serious terminal injury to shoots.

Mesogramma marginata Say, predator of *Cinara*.

HYMENOPTERA

Alaptus sp., parasitises *Acutaspis perseae*.

Aphytis chrysomphali Mercet
Aphytis diaspidis Howard
} parasitise *Acutaspis* and *Lepidosaphes*

Apis mellifera L., colonises holes made by *Kalotermes* spp.

Aspidiotiphagus citrinus Craw, parasistises *Acutaspis*.

Aspidiotiphagus lounsburyi Berlese & Paoli, parasitises *Acutaspis, Carulaspis* and *Lepidosaphes*.

Callimome sp., bred from *Contarinia juniperina*.

Inostemma sp., parasitises *Contarinia juniperina*.

Pheidole megacephala F., attends Cinara and preys on *Kalotermes* spp.

Prospaltella spp., parasitises *Acutaspis, Carulaspis* and *Lepidosaphes*.

Chronological Review

The diseases and pests of the Bermuda cedar attracted little attention in the Islands until 1930, when a scale insect hitherto unrecorded was reported causing severe injury to foliage at Tucker's Town (6). The pest was first identified as *Chrysomphalus agavis* Ths. and Ckll., and later determined by Ferris as *Acutaspis perseae* Comstock. The pest was not found confined to the infested area but was common throughout the Islands. Two further outbreaks were found in the following year at Warwick Academy and Hinson's Island (7). In both these cases, two hymenopterous parasites were found, *Aphytis diaspidis* Howard, and *Aspidiotiphagus citrinus* Craw. The outbreak of cedar "blight" was thought due to a temporary upset in the biological control by these parasites.

The observations at this time, of E. A. McCallan, then Director of Agriculture, are of interest. In correspondence with Prof. H. H. Whetzel (September 7, 1931) he wrote :

> I have lately returned from Hinson's Island (opposite Darrell's Wharf). There we found a sad condition in the cedars. It is much worse than I expected to find it. A few trees are dead, many are nearly dead and scarcely any are thrifty. They are all sparsely covered with foliage which looks lifeless. The cause has been put down to scale and this may be the truth, but I was surprised to find so little scale about.

Later McCallan wrote (October 21, 1931) :

> As to the scale on cedars, now that we have had rain, the affected trees appear to be reviving very rapidly. You must remember that we had practically no rain all summer. We have done very little spraying, which I think is of more value as a demonstration than as anything else.

Control had been claimed by the use of lime-sulphur spray (6).

The trouble evidently abated the following year, since no further mention is made in the Annual Reports of the Department of Agriculture until 1935, when T. A. Russell reinvestigated the situation (25). Two species of mites were reported, one an *Eriophyes* sp., causing a swelling to the tips of the twigs, and the other resembling a small red spider. None of the insects or mites found appeared to be sufficiently harmful on its own to cause extensive damage. In July, 1937, the writer observed small patches of cedars about three or four acres in extent showing a marked browning of the foliage, which was accentuated where the trees were over-crowded. No pests of importance were found at the time and it appeared that the injuries from which the junipers were suffering had taken place some months earlier (32).

In 1943, an opportunity arose to study the cedars earlier in the season. The trees on Hinson's Island again became affected very much as McCallan had described them in 1931. The writer (37) found three pests in great abundance in early May, an aphid, *Cinara juniperi* De Geer (listed as *Neochmosis* sp.), the Fulgorid, *Ormenis infuscata* Stal., both feeding on the branches and causing a pronounced yellowing of the leaves accompanied by defoliation, together with a Cecidomyiid, *Contarinia juniperina* Felt, which produced a russet-coloured terminal die-back of the shoots locally known as "blight". At the same time, a careful check was made for the presence of fungous disease on injured foliage. Only one species, *Gymnosporangium bermudianum* (Farl.) Earle, appeared to be parasitic in a minor way. *Pestalotia conigena* Lev., and *P. micheneri* Guba, were secondary invaders in moribund shoots. Altogether some 56 species of fungi have been recorded on the juniper (41).

In view of the entomological nature of the juniper injuries, an invitation to visit Bermuda was extended to Dr. R. L. Parker, Kansas State College, who had been working on the juniper midge problem in North America. Dr. Parker visited the Islands during March–June, 1945, and made a survey of the pests attacking the cedars (23). Although his report did not add anything new to the list of insects already recorded, it did show the need for further fundamental research work.

On the writer's return to the Colony in October, 1945, after a year's leave of absence, two new pests were found to be causing serious damage to the cedars, in two separate localities. One of these, the oyster shell scale, *Lepidosaphes newsteadi,* had been collected previously by Russell at "Paynter's Vale", Harrington Sound, in December, 1944. It did not appear at that time to be a pest. The other species, the juniper scale, *Carulaspis visci,* which was not reported by Parker, was first collected by W. R. Evans in August, 1945, at "Chelston", Paget, where it was found infesting an area of about three acres (39). It was soon evident that both these insects were likely to cause more serious damage to the cedars than any other pests previously recorded.

The present pest complex of the Bermuda Juniper has therefore two distinct phases. The first developed during the period 1930 – 1944, and was represented by a relatively ephemeral type of infestation of defoliating insects and mites which built up during the winter and spring months and reached a climax during April and May, disappearing from the foliage by the end of June. The intensity of the infestation varied with the amount of rainfall, and the growing conditions of the trees. One infestation of a permanent type was represented by the scale *Acutaspis perseae,* which was rarely observed to cause serious damage.

The second phase developed in 1945 with the appearance of two further infestations of a permanent type, represented by the oyster-shell

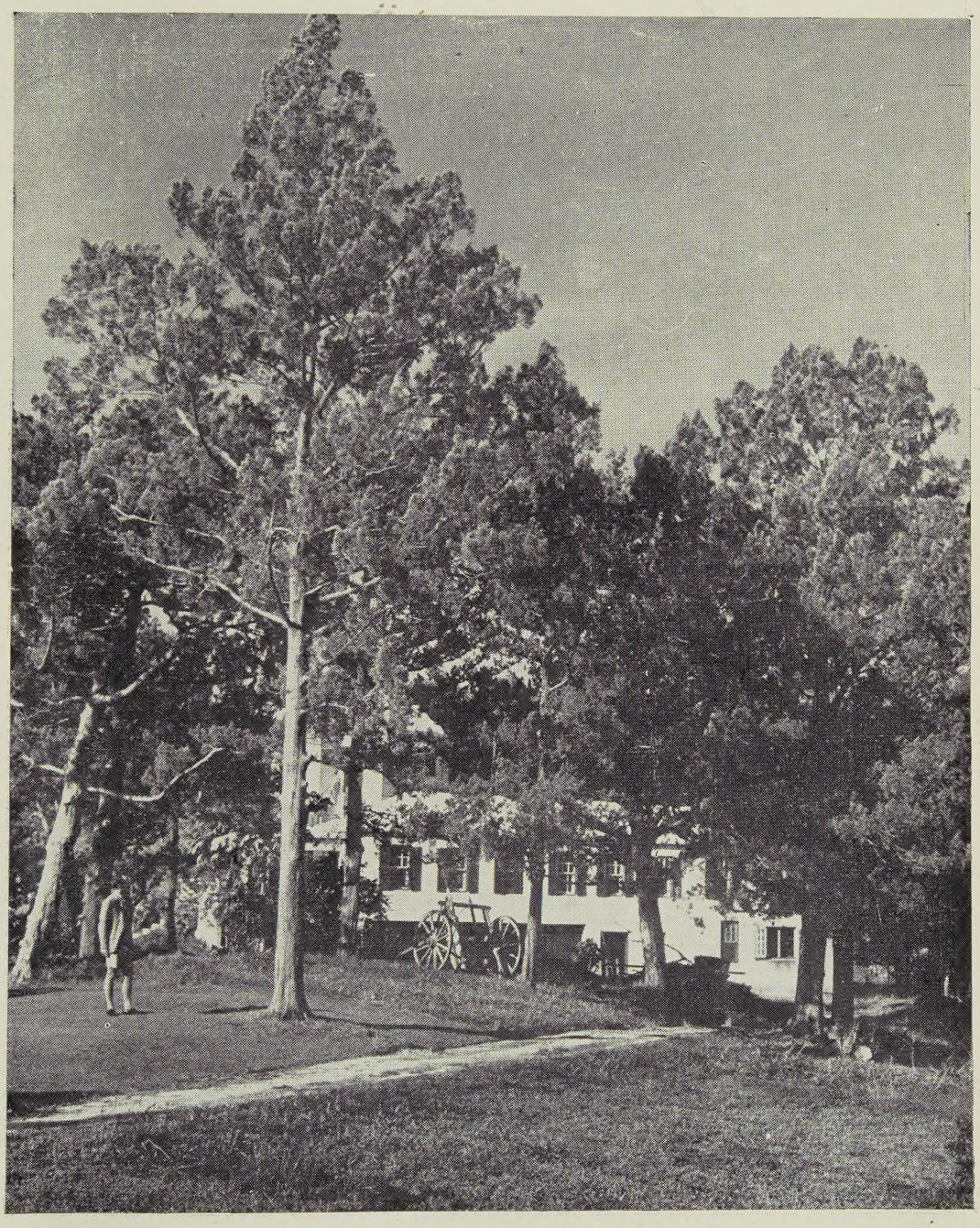

FIG. 1. Healthy Bermuda cedar, 35 years old, showing habit. Older trees are in the background.

FIG. 2. Old injury caused by juniper aphids, *Cinara juniveri*, on Bermuda cedars growing in an overcrowded condition on thin soil. Note freedom of injury of upper portions of the trees and the rocky foreground.

FIG. 3. Pruned cedars, 8 years after treatment, showing recovery from juniper aphid injury. Compare proportions of uninjured foliage with un-pruned trees in Fig. 2.

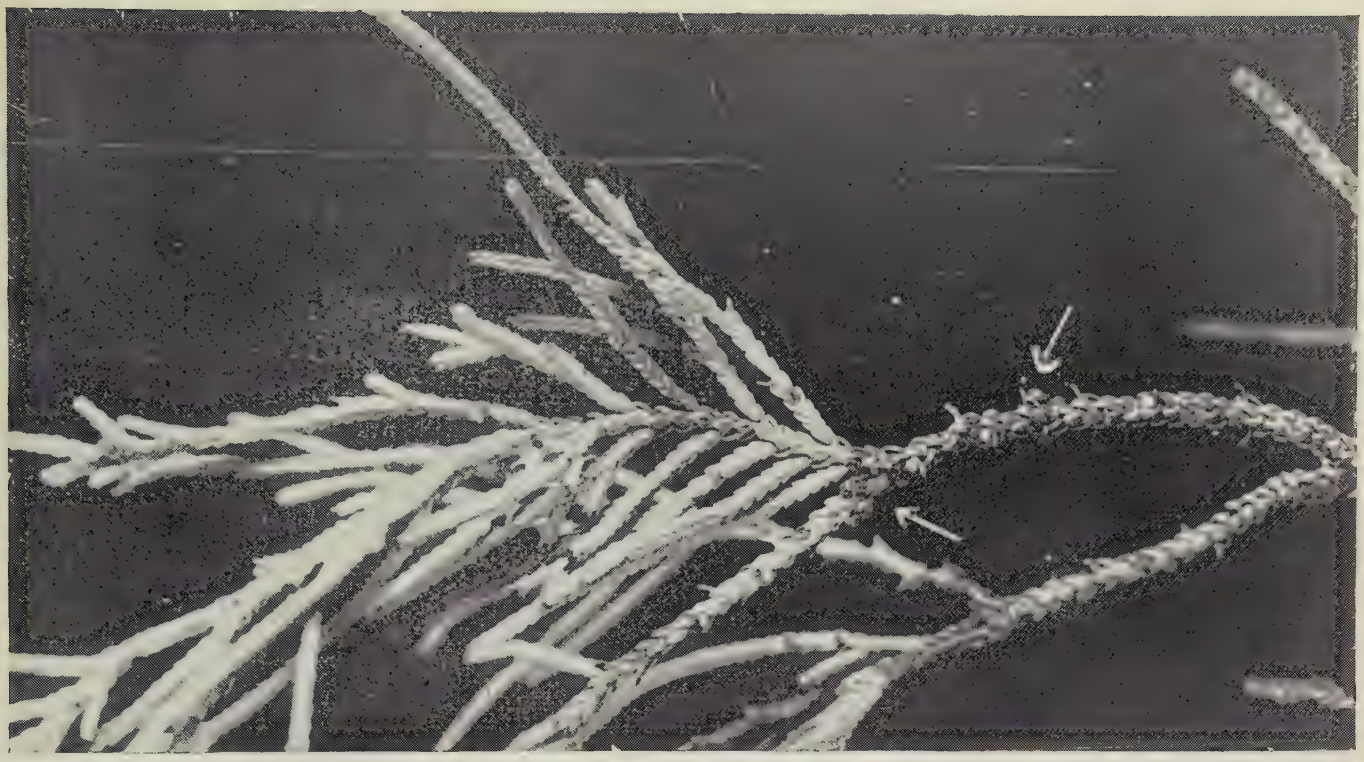

FIG. 4. Groups of juniper aphids feeding on the bark at the base of cedar twigs. X 1½.

FIG. 5. Bermuda cedar twig on the right showing defoliation caused by juniper aphids.

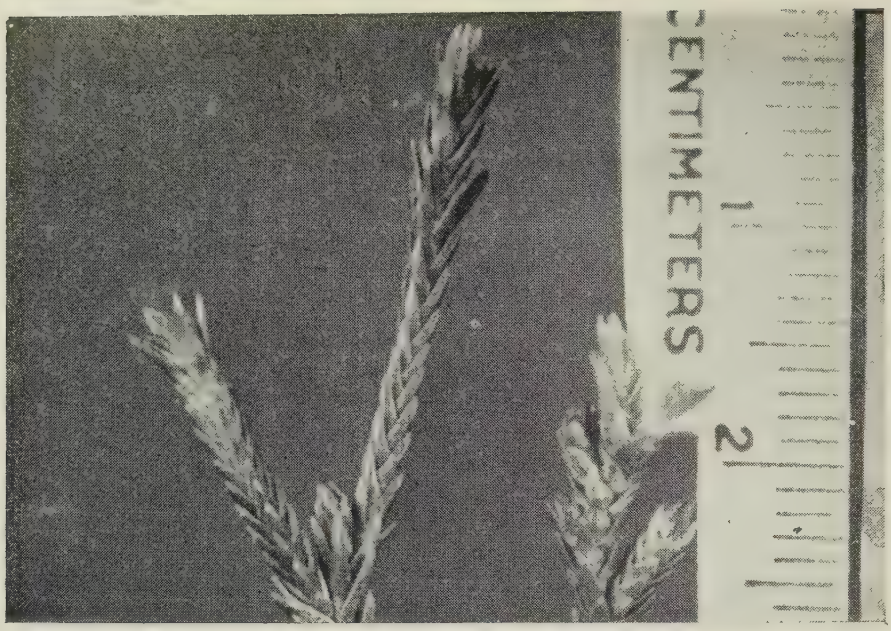

FIG. 6. Typical terminal swellings on shoots of Bermuda cedar caused by tunnelling larvae of the juniper midge, *Contarinia juniperina*. X 3.

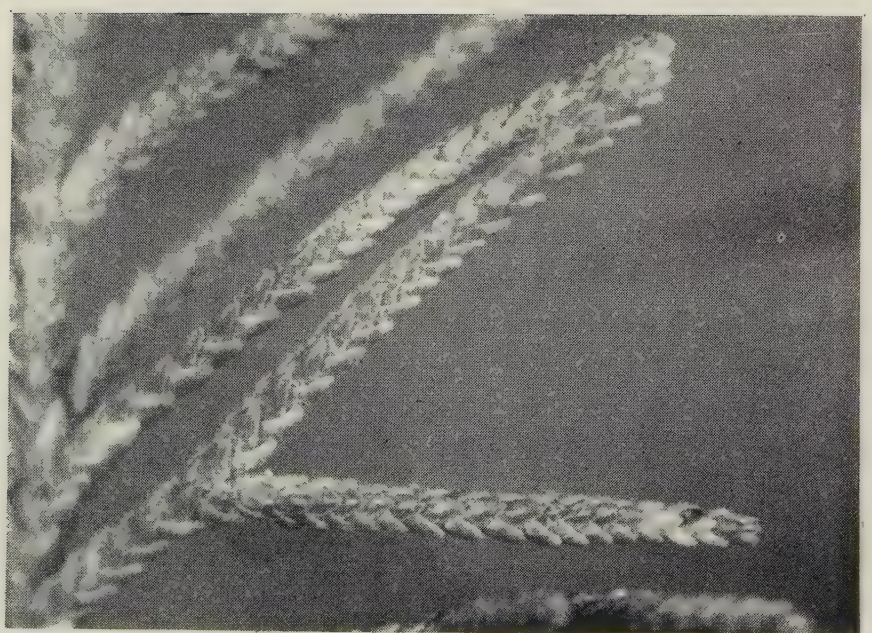

FIG. 7. Bermuda cedar leaves showing type of mottle caused by the spruce mite, *Paratetranychus ununguis*. X 4.

scale and the juniper scale. These increased very slowly during the winter months, but were very active from May to October, reaching a peak in August. Trees damaged by these species showed no signs of recovery.

Major Pests of Foliage

The pests of juniper foliage are here treated in two groups, those associated with the old cedar "blight" complex, and those comprising the scale insect infestations. Of the first group, three species are important sap suckers, the juniper aphid and the leaf hopper on the twigs, and the spruce mite on the leaves, resulting in rapid defoliation. In addition, larvae of the juniper midge tunnel in the shoots, destroying the vascular system with resulting terminal injury.

Cedar "Blight" Complex

The Juniper Aphid. The juniper aphid, Cinara juniperi De Geer *(Panimerus juniperi* De Geer) has previously been reported from both North and South America, as well as Europe, on the following hosts : *Biota, Juniperus* (2 species) and *Thuja.* The aphids cause serious damage to the Bermuda cedar, particularly on the lower branches (Fig. 2). The first signs of infestation appear as uniformly yellow patches of foliage scattered throughout the lower limbs of the tree, generally in April, if the weather is dry. In a few weeks the whole shoot is completely defoliated. The worst affected trees appear in patches of thin soil or where they are overcrowded. Pruning the cedars appears to check the infestation and brings about some measure of recovery (Fig. 3).

The defoliation results from the aphids feeding in groups on the bark at the base of the cedar twig. (Fig. 4). The aphids are dark brown in colour and rather difficult to distinguish from the bark. Their presence is usually indicated by the ant, *Pheidole megacephala,* which tends them and aids in their dissemination. Nymphs have been recorded as early as December, sometimes associated with a rapid browning and die-back of young tender shoots. Defoliation, however, is the more general result of injury. Winged forms appear from March, onwards. Towards the end of May, the aphids become scarce and leave no evidence of their presence apart from bare, defoliated twigs (Fig. 5). No egg stage has yet been found.

Attempts made by the writer to induce defoliation of two year old seedling trees in pots failed, although as many as 100 aphids were transferred to a single plant. Trials made with larger trees might have proven more successful. Field observations indicate the juniper aphid to be the most serious pest of the Bermuda cedar apart from scale insects.

Few natural enemies have been found. Two predator hover flies, *Allograpta obliqua* and *Mesogramma marginata,* and the lace-wing, *Chrysopa rufilabris* have been collected, but none appears to exert any effective control. No parasites have been seen. *Lysiphlebus testaceipes* is exceedingly common on the melon aphid, *Aphis gossypii,* but has not been observed on the juniper aphid.

The Juniper Midge. The juniper midge, *Contarinia juniperina* Felt, was found well established in Bermuda in 1943 (36), five years after it was first discovered as a new species by Felt (11) in North America. Reports of its attack on *Juniperus virginiana* have been made by Parker and Wenger (24) and Haseman and McLane (15). The larvae cause serious injury to local patches of Bermuda cedar by tunnelling into the terminal portions of the shoots. The affected twigs are pale yellow at first, and later become swollen and orange-maroon in colour (Fig. 6.). Eventually the larvae either leave the twig and drop to the ground to pupate in April, or they pupate *in situ.* Symptoms start to develop on the foliage in February and become very conspicuous by April. Severely infested trees turn a rusty brown colour, a condition known locally as "blight". The dead tip growth persists on into the summer, but eventually falls off, leaving the tree thin and sparsely covered with foliage. Young trees growing under unfavourable conditions may be killed by the infestation. Older trees show recovery at the onset of wet weather in the autumn. Several overlapping generations are found in Bermuda. Larvae have been seen in the twigs in January, March and November and pupae collected in the twigs in May, August and September. Adults appear in January and are common by May.

Two hymenopterous parasites occur, one a species of *Callimome,* was reared from infested foliage in March and another a species of *Inostemma,* collected in May. Their effectiveness has not been determined.

The Spruce Mite. The spruce mite, *Paratetranychus ununguis* Jacq., has been reported as a pest of conifers from very widely spread regions : in the United States of America and Canada, Bohemia, Czechoslovakia, England, Germany, Holland, Norway, Sweden and New Zealand. The following hosts have been reported. With the exception of *Buxus* and *Quercus* all are coniferous : *Abies* (2 species), *Buxus, Cryptomeria, Larix, Picea* (5 species), *Pinus* (3 species), *Pseudotsuga, Quercus, Sequoia* and *Thujopsis.* The mite has been known in Bermuda since 1935 but was only recently identified (39). Its feeding habits remove the sap from the leaves causing the formation of a characteristic mottle (Fig. 7). The leaves

later turn brown and drop off. The mite builds up in numbers during the autumn and winter months especially in dry weather, to serious proportions, but disappears after heavy rain. Eggs are frequently found on the twigs in June.

Sprays applied during March to May and containing 97% wettable sulphur ("Sulforon", 8 lbs. in 100 gallons water) gave some control, but "Gesarol" AK (50% "D.D.T."), 2 lbs. in 100 gallons water, caused a significant increase in the numbers of the mites over the control plots.

There has been some speculation as to the part played by predisposing factors favouring mite injury. Cunliffe and Ryle (5) found no evidence that sickly or suppressed sitka spruce were attacked in preference to healthy ones. Young trees were found to be most heavily infested, an opinion shared by Garman (12). Later Cunliffe (4) thought that bad sylvicultural practices, especially defective drainage, might favour attack on *Picea*. Dumbleton (9) found isolated trees or single lines of *Picea* suffered the greatest defoliation. In Bermuda, the infestation appears to develop in epidemic form during periods of drought and has most effect on junipers growing under poor conditions.

The Juniper Leaf Hopper. The juniper leaf hopper, *Ormenis infuscata* Stal., has been known for many years in Bermuda, but has only recently been suspected as a pest (37). It is a sap sucker causing defoliation similar to that of the juniper aphid. The adults have also been found associated with a rapid form of injury on young shoots, caused possibly by a toxicogenic effect of their saliva (37).

The eggs, pink in colour, are concealed under a dense, white, waxy covering, situated on the inner surface of dead leaves clothing the base of the shoots. The nymphs begin to emerge in February and continue up to April. They pass through several moults. Adults become numerous by March, but disappear by the middle of June. No parasites have been found, but the lace-wing, *Chrysopa rufilabris* has been seen preying on the nymphs.

Scale Insects

The oyster-shell scale, *Lepidosaphes newsteadi* Sulc., and the juniper scale, *Carulaspis visci* Schr., both of recent introduction, are the two most serious pests infesting the Bermuda cedar at the present time. The former was first recorded in 1944 and the latter in 1945 (39). The centres of origin and the present extent of the infestations are shown in Fig. 8.

The Oyster-Shell Scale. The oyster-shell scale, *Lepidosaphes newsteadi*, has been previously recorded from the United States of America; from Bohemia, Czechoslovakia, Lithuania, Italy and Germany in Europe, and from Japan. The following are among the hosts listed: *Chamaecyparis, Cryptomeria, Juniperus, Pinus* (3 species), *Podocarpus, Sciadopitys, Sequoia, Taxus* and *Thuja*. The pest, of European origin, appears to have reached North America on *Sciadopitys verticillata* from Japan (17). Later Felt (10) reported the infestation on this host was sufficient to check the vigour of the tree. No other records of host injury appear to have been made. Studies of the life cycle of the insect do not occur in the literature.

Nothing is known of the date of introduction into Bermuda. It may have entered on nursery stock at the Castle Harbour Hotel some years previous to 1944. At the present time the infestation is scattered irregularly over an area 9 miles wide.

The foliage of affected trees is pale-yellow in colour. When the infestation is severe, the tree is killed rapidly, the whole presenting a uniformly tan-coloured appearance (Fig. 9).

The pest appears more conspicuous on the berries than on the foliage (Fig. 11). The degree of infestation varies, with some trees showing what appears to be resistance to attack. This, however, may merely be a klendusic effect.

No detailed studies of the life cycle have been made. The scale insects pass the winter in a dormant state. The formation of eggs was seen towards the end of February but these were not laid until March. Crawlers have been recorded commonly between July and November but probably occur earlier in the year. Males have been found in January and October.

Few parasites have been recorded on the oyster-shell scale in Bermuda, and none appears listed in the literature. *Aphytis chrysomphali, Aspidiotiphagus lounsburyi* and *Prospaltella* sp., have been bred from material collected in the field, but their incidence is low and does not constitute effective control. This lack of parasites and predators makes the oyster-shell scale the greatest single threat to the Bermuda juniper at the present time.

An attempt has been made to introduce a predaceous species of mite, *Hemisarcoptes malus*, which feeds on the eggs and adults of a closely related species, *L. ulmi* on apples in Canada. Since the latter does not occur in Bermuda, the shipment of the mite in a viable condition in the absence of its host presents some difficulties.

FIG. 8. Outline map of Bermuda showing distribution of infestations of *Lepidosaphes newsteadi* and *Carulaspis visci*, May, 1947. Arrows indicate the centre of origin.

An interesting fungous parasite found attacking *Lepidosaphes newsteadi* on Bermuda juniper during February and March, has been tentatively identified as *Myiophagus ucrainicus* (Wize) Sparrow by Karling (15a) and placed in the chytrid family *Achlyogetonaceae (Septolpidiaceae)*. Whether this chytrid will be effective in checking *L. newsteadi* on juniper in Bermuda still remains to be determined. It also attacks *L. beckii* in Bermuda. Counts of females of the latter on sour orange seedling stems revealed over 40 per cent killed as a result of its parasitism. The material has been tentatively identified by Prof. J. S. Karling (personal communication) as a member of the Septolpidiaceae (Chytridiales). The chytrid was also observed attacking *L. beckii* on sour orange in Bermuda, and *L. ulmi* on apple twigs obtained from Canada. The effectiveness of this parasite has yet to be assessed.

Spraying experiments using Sherwin Williams' " Citromulsion " (83% Hydrocarbon—oil, viscosity 70—75 seconds Saybolt at 100°F.) diluted to 2% (1.7% actual oil), gave some control when applied in February. Oil injury however was observed when applications were made after April.

The Juniper Scale. The juniper scale, *Carulaspis visci*, has been recorded as a pest of conifers from the United States of America and Canada; from Puerto Rico; from Belgium, Czechoslovakia, France, Italy and Spain in Europe; from Algeria and Morocco in North Africa and also from Japan. The number of hosts is extensive and includes the following: *Biota, Chamaecyparis* (4 species), *Cryptomeria. Cupressus* (6 species), *Juniperus* (16 species). *Libocedrus, Picea, Pinus* (3 species), *Sequoia, Taxus and Thuja* (2 species).

As far as can be ascertained, *C. visci* was introduced at "Chelston", Paget, on coniferous nursery stock imported from California in December, 1942. No damage to local junipers was observed until a little over 2½ years later. The main area infested by juniper scale is at present approximately 2½ miles long by ½ mile broad, and is centred in the heart of the Colony in a residential area opposite the capital city of Hamilton. Infested trees may succumb within a period of two years (Fig. 10). Few studies have been made on the life-cycle of this species. According to McDaniel (19), in Michigan the mother scale passes the winter as a nearly mature individual and the young appear on the foliage in June, with apparently only one generation in a year. This is not the case in Bermuda, where several overlapping generations are found. Crawlers and males have been found throughout the year but are most abundant during the summer months.

Up to the month of May, the infested areas remain apparently static. Thereafter the trees show a rapid greying of the foliage due to the growth and multiplication of the scale insects which reaches a peak in August, when the trees seem almost white. Little spread is observed after October.

Wind appears to be the main agent in disseminating the crawlers. Where isolated trees are found infested, the affected branches face towards the centre of origin of the outbreak. Frequently the tops of the trees are infested first.

Three parasites have been reared from the juniper scale in Bermuda. These are *Aphytis diaspidis, Aspidiotiphagus lounsburyi* and *Prospaltella* sp. Of these, *A. lounsburyi* is by far the most important species, the incidence of its parasitism in the field reaching as high as 90 per cent in many instances. (Fig. 12.). Attempts to control this pest by biological means have not been reported in the literature. Other parasite records are *Aspidiotiphagus severiniellus* Ghesq., from Belgium; *A. citrinus* Craw, from Puerto Rico; *Aphytis mytilaspidis* Le B., from Belgium and the U.S.A.; and *Euaphycus botanicus* Mercet from Spain. Packard (22) observed *A. mytilaspidis* appeared to reduce the numbers of the scale on juniper at Washington, D.C. A coccinellid predator, *Chilocorus bipustulatus* L., has been reported from Morocco by Bouhelier (3) as effectively reducing *C. visci* on *Cupressus.*

The Black Cedar Scale. The black cedar scale, *Acutaspis perseae* (formerly listed as *Chrysomphalus agavis*) is the third species of importance on Bermuda cedar. It has previously been recorded from the southern states of North America on many hosts including *Pinus.* It is known only on juniper in Bermuda (6) where it was first recorded as a pest of importance in 1930. The toxic effect of this species on its host is not nearly so pronounced as that of *Lepidosaphes* and *Carulaspis* (Fig. 13).

A severe attack may cause greying of the leaves and subsequent partial defoliation or may commonly cause merely a stunting of the shoots. Trees are rarely killed outright as is the case of attack by the other two species.

Cunningham (7) found the amount of damage varied from year to year and attributed this to fluctuations in the populations of the parasites, *Aphytis diaspidis* and *Aspidiotiphagus citrinus.* These were found to be difficult to breed out of parasitised material, a fact which recent observations have confirmed. It should be noted that *A. citrinus* is apparently restricted to this host and *Comstockiella sabalis* in Bermuda, and is not nearly so abundant as the other species *A. lounsburyi* which has five hosts (Table II.). Other parasites recently recorded are *Alaptus* sp., *Aphytis chrysomphali, Aspidiotiphagus lounsburyi* and *Prospaltella* sp.

Minor pests of Foliage

There are several minor pests of juniper foliage which have been little studied. The cedar looper, *Thamnonoma ochrifascia* is common in the larval stage from January to June, when it passes through several generations. Eggs have been found as early as January. Plant bugs, *Lygus* sp., and leaf hoppers, *Deltocephalus* sp., are also very numerous in the spring. Another plant bug, *Banasa euchlora,* has been recorded feeding on berries and foliage in late summer. Its status as a pest is not known. Two mealy bugs, *Orthezia insignis* and *Pseudococcus* sp., are also seen occasionally but are of no importance. A weevil, *Anthonomus juniperinus* has been collected in January. It is known in the eastern part of the United States of America, living on fungi that infest junipers.

Other Pests

When branches are injured by defoliating insects and begin to die-back, they are attacked by two borers, *Oeme linearis* and *Leptostylus praemorsus*. The latter tunnels under the bark, which is eventually stripped off, paving the way for invasion by the dry-wood termite, *Kalotermes approximatus,* which hollows out the heart wood of the trunk. As a result of neglect in pruning, over a third of the cedars in Bermuda are prematurely hollow. According to Prof. A. Emerson (personal communication) there are at least two other species of dry-wood termite attacking Bermuda cedar, *Kalotermes snyderi* and *Cryptotermes cavifrons*. Further studies are indicated. A fungous parasite, *Delacroixia coronata* has been found to attack *Kalotermes* spp., from Bermuda cedar in the laboratory (37). It is not known whether this occurs in nature.

The roots of the cedars are attacked during the winter and spring months by the nymphal stage of the "Bermuda Singer" *Cicada bermudiana*. The adults emerge regularly every year in the early part of June as is shown in Table III, which gives a ten-year record of the date when the strident notes of its "song" are first heard.

TABLE III

Showing Record of First Date the "Bermuda Singer" has been heard over a Ten-Year Period, 1937–1946

Year	Date
1937	June 10th
1938	No record
1939	June 13th
1940	No record
1941	June 23rd
1942	June 15th
1943	June 5th
1944	June 5th
1945	No record
1946	June 13th

Miscellaneous Injuries

The Bermuda cedar suffers from an assortment of injuries, the chief ones being removal of the bark by horses and cows in search of a "salt lick", and the careless ringing of the trunk by wire used in fencing and tethering animals. Lightning occasionally strikes the tops of trees and causes a sudden die-back for a distance of several feet. The bark of the trunk may sometimes show cracks as a result.

Salt spray may temporarily scorch the foliage during winter storms. The leaves are turned brown in colour, sometimes only half of the surface being affected. Abnormally high tides which raise the water table, have also been observed to bring about the death of trees through the roots being brought into contact with underlying salt water.

Poultry confined under the junipers cause the foliage to turn yellow, eventually bringing about the death of the trees due apparently to an excess of ammonia near the roots supplied by their droppings.

Finally, there is the intrusion suffered by the competing "weed" trees, *Citharexylum spinosum* and *Pimenta officinalis,* which have successfully usurped the endemic cedar in several parts of the Islands, through competition of water and light. Unlike the junipers, these trees form a dense canopy which does not permit the growth of a protective carpet of *Stenotaphrum secundatum*. This lack of ground cover enhances the danger of further erosion of an already depleted soil.

Discussion

The control of insect infestations on the endemic cedar is of serious concern in Bermuda. The tree may have little intrinsic commercial value yet its importance from aesthetic considerations in a residential area dependent on a tourist trade is very great. It is doubtful whether any other tree could so successfully combine tolerance to xerophytic conditions with the ability to perpetuate its species unaided by man on the bare, wind-swept limestone soil of the Islands. Spraying as a control measure is impracticable owing to the lack of a water supply, the inacessible nature of the terrain as well as for economic considerations. Tree surgical methods have proved beneficial in assisting recovery from attack by aphids, juniper midge, and spruce mite, but are quite ineffective in controlling scale insect infestations.

The logical solution to the problem lies in the use of biological control. The Bermuda Islands by virtue of their isolated position and limited size, offer favourable opportunities for the employment of this method. Apparently Verrill (29) was the first to appreciate this and to suggest that various Coccinellids be introduced including species of *Novius, Orcus* and *Rhizobius (Lindorus)* to control the many

FIG. 9. Bermuda cedar on the left is severely infested with oyster-shell scale, *Lepidosaphes newsteadi*. "Coral Ledges", Harrington Sound, November, 1946.

FIG. 10. Group of mature Bermuda cedars completely defoliated and killed by juniper scale, *Carulaspis visci*. "Chelston", Paget, November, 1946.

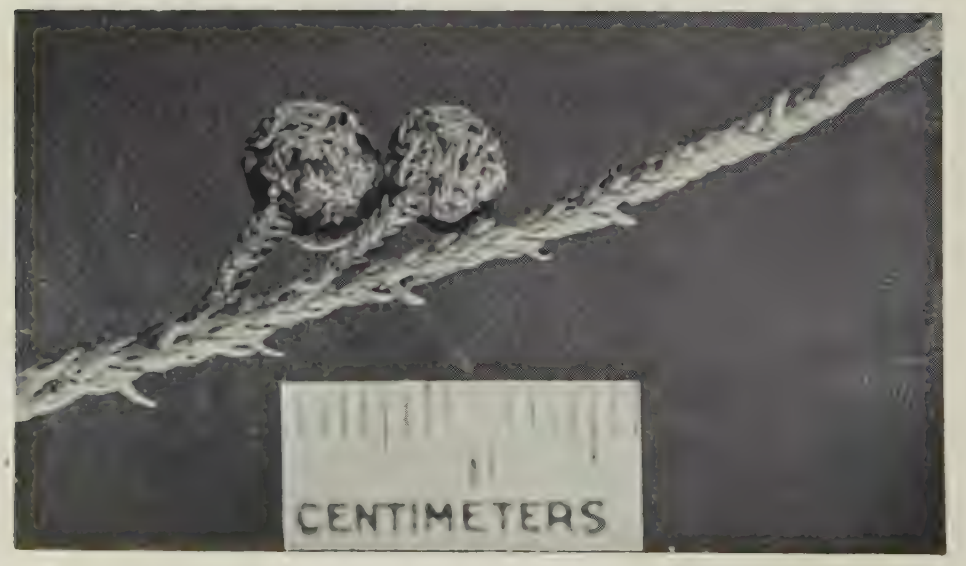

FIG. 11. *Lepidosaphes newsteadi* on berries of Bermuda cedar. X 2½.

FIG. 12. *Carsulaspis visci* on foliage and berries of Bermuda cedar. A female centred on the berry to the left shows an exit hole of the chalcid, *Aspidiotophagus lounsburyi*. X 2½.

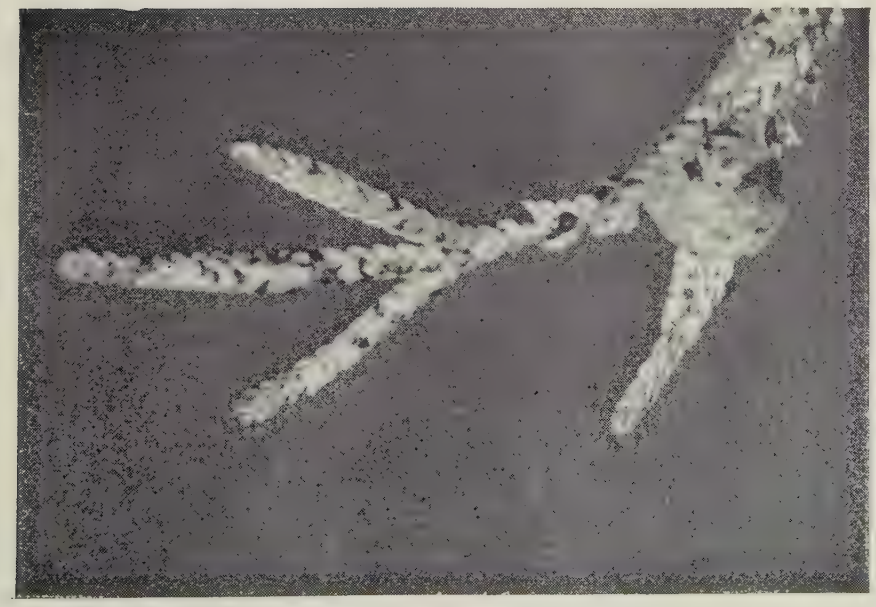

FIG. 13. *Acutaspis perseae* on foliage and berries of Bermuda cedar. X 2½.

different kinds of scale insects flourishing in Bermuda. As a result, *Novius cardinalis* Muls., was introduced in 1902 from the United States of America and became successfully established as a predator of the cottony cushion scale, *Icerya purchasi*. A further attempt to introduce Coccinellids was made in 1924. According to Ogilvie (20) :

> Through the courtesy of Prof. Silvestri. Italy two predatory ladybird beetles, *Chilocorus bipustulatus*, and *Rhizobius* (*Lindorus*) *lophanthae*, were included in a further consignment of *Aphytis diaspidis* infested twigs sent during the spring. The former was bred in the greenhouse and proved a very active predator of *Aulacaspis pentagona*. Planting of the beetles outside however, have apparently failed to become established.

The absence of rapid means of transport, and the small number of beetles received would easily explain the failure of this attempt. There is, however, a noteworthy absence of Coccinellids in Bermuda in spite of an abundance of suitable hosts. Ogilvie (21) lists only three species. The possibility of introducing further members of this useful family for the control of juniper pests is at present being investigated by the Imperial Bureau of Biological Control.

Better success has attended the use of parasites for the control of two scale insects accidentally introduced from the West Indies, the "Oleander" scale, *Aulacaspis pentagona*, and the "Palmetto" scale, *Comstockiella sabalis*. The history of these pest introductions has a parallel with the present ones infesting the junipers. According to E. A. McCallan (personal communication), *A. pentagona* was first observed on oleanders, *Nerium oleander*, at "The Manse", Paget in 1917, half a mile distant from "Chelston", where *Carulaspis visci* was first recorded on juniper. The pest became established over a wide area by 1920, infesting 27 different hosts (35), and killing many oleanders. No parasites were reported at this time. In 1921, *Prospaltella berlesei* and *Aphytis diaspidis* were imported from Italy (42). The latter became rapidly established and exerted visible control by 1923.

Comstockiella sabalis on the other hand, was first reported on the endemic palmetto, *Sabal bermudana*, in the extreme eastern portion of the Islands at St. George's, 3½ miles from the point where *Lepidosaphes newsteadi* was first observed. Unlike *A. pentagona*, the scale took 13 years to traverse the Islands from east to west. In 1926 and 1929, *Aphytis fuscipennis*, *A. mytilaspidis*, *Encarsia portoricensis*, and *Physcus sp.*, were imported from the United States of America for the control of the scale. By 1936, these parasites had become well established and the depredations of the scale insect effectively checked (30). Occasional outbreaks of both oleander and palmetto scale still take place, but they never reach the proportions attained at the time of their introduction.

A search for suitable parasites of the juniper scale insects is being made at the present time by the Imperial Bureau of Biological Control. This is most needed in the case of *Lepidosaphes newsteadi*, which does not appear to possess any effective parasites. On the other hand, *Carulaspis visci*, exhibits such a high degree of parasitism by *Aspidiotiphagus lounsburyi*, that the possibility exists of the latter eventually bringing the pest under control. This Chalcid was unknown in Bermuda prior to the discovery of *C. visci*, when it was found coextensive with its host. It has since been recorded on four additional hosts, and appears to have been introduced along with the juniper scale. The present distribution of the chief scale insect parasites is shown in Table IV.

In January, 1947, Dr. W. R. Thompson, Director, Imperial Bureau of Biological Control, visited Bermuda and established a field laboratory at Hamilton, for the purpose of studying the possibilities of introducing beneficial insects for the control of the juniper infestation. A preliminary report has already been published (27) and the investigation is still in progress.

SUMMARY

The present pest complex affecting the Bermuda cedar can be divided into two phases. From 1930 – 1944, the chief pests causing injury to foliage were aphids, *Cinara juniperi*, juniper midge, *Contarinia juniperina*, spruce mite, *Paratetranychus ununguis*, leaf-hoppers, *Ormenis infuscata*, and the black cedar scale, *Acutaspis perseae*. These were seasonal in their incidence, reaching epidemic proportions during dry weather and disappearing at the onset of heavy rain. Trees were rarely killed outright, and then, only when growing in over-crowded conditions or on very thin soil. Affected trees usually made recovery when thinned and pruned.

During 1945, two pests new to Bermuda, an oyster-shell scale, *Lepidosaphes newsteadi* and the juniper scale, *Carulaspis visci*, made a sudden appearance and threatened to exterminate the endemic juniper. Trees were killed by both species within two years from the onset of infestation.

The incidence of parasitism on the juniper scale by *Aspidiotiphagus lounsburyi* is high, but it is not known yet whether the Chalcid will hold the pest in check. No effective parasites of the oyster-shell scale are known.

A further search for parasites and predators is being undertaken at the present time by the Imperial Bureau of Biological Control, which has established a field laboratory in the Islands.

TABLE IV

Summary of Parasite Records of Six Important Scale Insects in Bermuda

Parasites	Hosts						
	Aulacaspis on *Nerium*	*Comstockiella* on *Sabal*	*Acutaspis* on *Juniperus*	*Carulaspis* on *Juniperus*	*Lepidosaphes* on *Juniperus*	*Lepidosaphes* on *Citrus*	Total
Alaptus sp.			+				1
Aphytis chrysomphali			+		+		2
Aphytis diaspidis	+		+	+			3
Aphytis fuscipennis	+	+					2
Aphytis mytilaspidis		+					1
Aspidiotiphagus citrinus		+	+				2
Aspidiotiphagus lounsburyi	+		+	+	+	+	5
Coccophagus flavoscutellum	+						1
Encarsia portoricensis		+					1
Physcus sp.		+					1
Prospaltella berlesei	+						1
Prospaltella diaspidicola	+						1
Prospaltella spp.		+	+	+	+		4
Thysanus niger ..		+					1
Total	6	7	6	3	3	1	

Acknowledgements

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THE PREPARATION OF ELEPHANT GRASS SILAGE AND ITS FEEDING VALUE FOR TROPICAL DAIRY CATTLE

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In most parts of the world where stock-keeping is practised periods of excess supplies of roughage alternate with periods of shortage within the year. The three common methods of carrying over the surplus roughage to the time of scarcity are haymaking, artificial drying and ensiling. Each of these methods has its advantages. Hay, whether dried naturally or artificially can be stored for long periods and transported far from its origin for feeding cattle. Unfortunately, haymaking is dependent on favourable weather conditions and artificial drying is expensive, particularly during wet weather when the crop has much adherent surface moisture. The ensiling process can be carried out in all but the wettest conditions and is relatively inexpensive. But because of its perishable nature silage cannot be fed other than near its place of origin.

In the wet tropics the preparation of hay is generally impracticable. Also the final product does not store well becoming mouldy and unusable within a short time. Under such conditions the ensiling process of conserving roughage is preferable.

A number of studies of ensiling have been undertaken at the Imperial College and the results were reported by Paterson (1945) in this Journal. The investigations were carried out on an experimental basis: small scale silos of various types were constructed, different methods of ensiling a series of crops were examined and the magnitude of wastages and the chemical composition of the silages were studied in detail. It is unnecessary to summarise the findings beyond saying that they shewed that almost any green crop can be ensiled under the prevailing conditions providing that an adequate procedure is adopted.

The purpose of the present work was to carry the investigation to its final stage, that is to study ensiling on a full scale stock farm basis under practical conditions. Elephant Grass (*Pennisetum purpureum*) was chosen as the crop to be ensiled. Attention was given to three aspects of the problem. First, general observations on the ensiling process were made and a time and cost study undertaken; as the process was under experimental control the time and cost study was vitiated to some extent because of the slowing down of operations by weighing grass loads and sampling the chaffed grass. Second, the losses from fermentation and spoilage were determined. Third, the feeding value of the silage as compared with freshly-cut Elephant grass was determined using dairy cattle in milk.

The Ensiling Process

All the work — excluding laboratory analysis — was undertaken at the Government Stock Farm. The silo was 14 feet 6 inches in diameter and was filled to a height of 15 feet 6 inches. The filling was completed in a period of four and a half days. For the first three days filling was continuous but on the fourth day heavy rain prevented work. Filling was completed during the morning of the fifth day.

The method of filling was that of common practice. The grass was chaffed to lengths of one to two inches and blown into the silo at a steady rate except when filling was interrupted to permit sampling. The chaff was spread evenly, the centre of the mass being kept somewhat higher than the edge at all times. Trampling was continuous, particular attention being given to consolidating the part near the wall. Periodically the surface of the chaff was sprayed with diluted molasses.

The Elephant Grass used came from a long established field. It was of reasonably good quality and of about three months' growth. The grass was cut daily and hauled to the base of the silo where it was weighed, as described below, chaffed and blown into the silo. Each day's filling was 24,000 pounds, the total quantity of grass ensiled being 84,000 pounds less 700 pounds withdrawn for laboratory analysis.

After each 3,000 pounds of chaffed grass had been blown into the silo, spread and trampled, the surface was sprayed with 3 gallons of molasses. The molasses were diluted with

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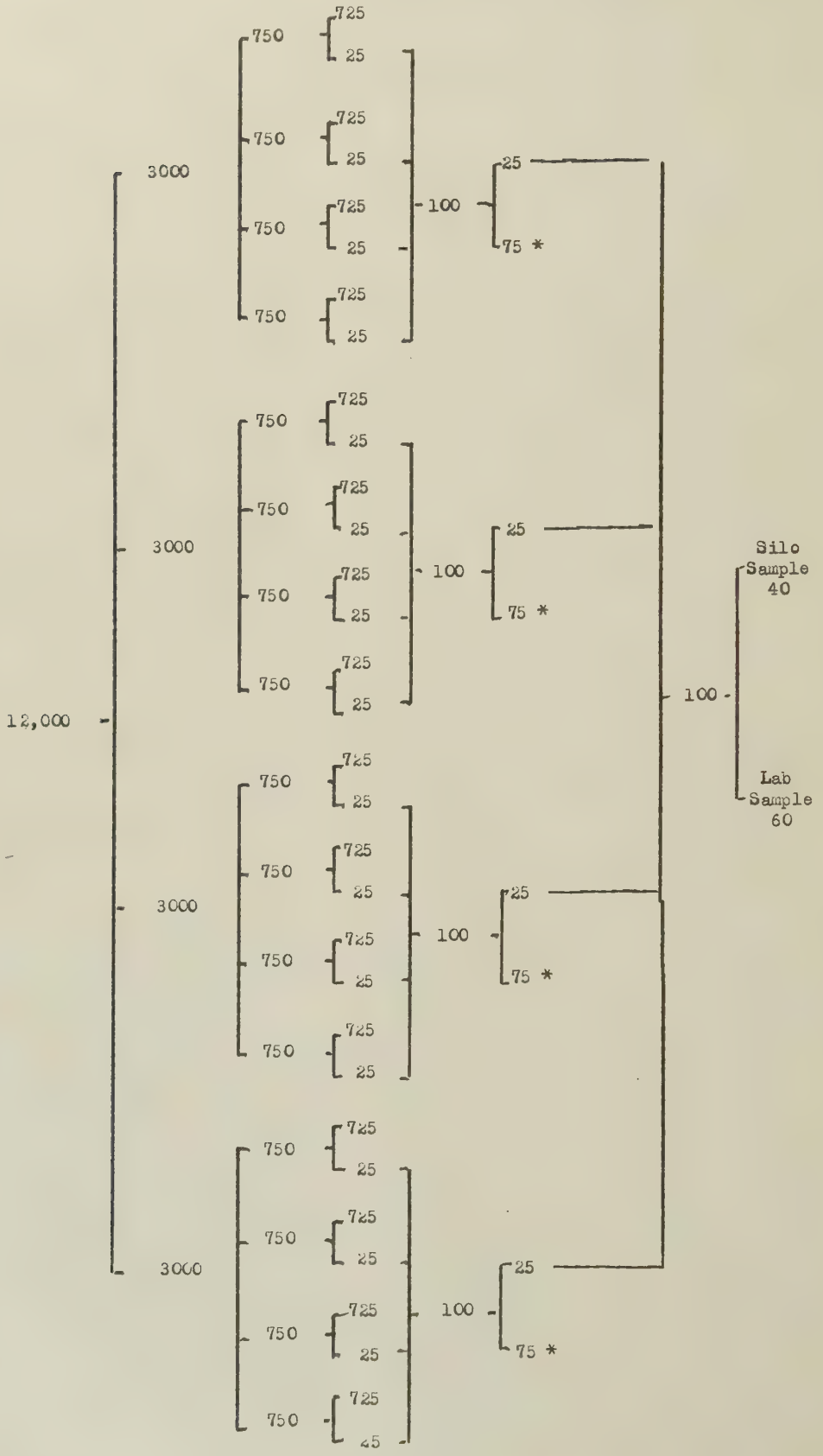
DIAGRAM. Illustrating sampling technique.



* Returned to silo.

water, the amount of which varied according to the dryness of the grass. In early morning when the grass was damp with dew the amount of water was reduced. During late afternoon when the grass was drier the dilution was increased. The maximum dilution was two gallons of water to one gallon of molasses.

At the conclusion of each day's filling the surface of the chaff was covered with boards previously prepared. When fitted together they formed a complete cover fitting the interior of the silo. They were weighted with sandbags.

When filling was complete the surface of the chaff was drawn into an even "dome", the grass sloping slightly downwards to the edge. A layer of unchaffed Elephant Grass was carefully laid on to form a seal. The boards described above were put in place and weighted with sandbags and iron bars.

Wastage

The measurement of the amount of wastage in a large scale process such as was undertaken in the present case is difficult. The problem is, in essence, that of drawing from the chaffed grass, during ensiling, and from the silage, during feeding, samples which are representative. It was essential that all the grass ensiled should be accurately weighed and that relatively large samples of chaffed grass should be taken at regular intervals. This demand, imposed by the experimental nature of the work, slowed down the filling process and materially increased costs. As will be shown below sampling to determine the magnitude of wastage necessitated a double handling of the grass at a scale and a complete stoppage of work while sampling.

As stated above, the ideal method of determining wastage also necessitates sampling all material withdrawn from the silo. To take daily samplings and make daily analyses throughout the emptying period was beyond our resources. We adopted a more practicable alternative. This involves drawing representative samples of chaffed grass during the filling of the silo and placing a portion of the representative sample in mesh bags. These bags are buried in the silo. As the silo is emptied the bags are withdrawn and the contents analysed. It is assumed that the changes occurring in the bags are representative of the changes occurring in the mass of the silage at corresponding levels.

Hitherto considerable difficulty has been experienced by workers in obtaining bags of suitable material. Cotton bags are attacked by the acid formed during the ensiling process. Metallic mesh bags are unsuitable because they are resistant to compression and because partial solution of the metal may influence profoundly the activity of micro-organisms locally leading to unrepresentative changes in at least some of the material within the bag. It occurred to us that the new plastic mosquito netting might be free from these drawbacks and seven bags, 54 by 18 inches were made, the seams being sewn with plastic thread. It was found that plastic net bags are highly flexible and allow normal compression of the contents.

The sampling technique is shown in the accompanying diagram.

The day's filling was set at 24,000 pounds of which half was ensiled during the morning and half during the afternoon. The morning and afternoon fillings were divided into four charges of 3,000 pounds each. A large platform scale was erected near the silo and provided with four wooden sides to retain the unchaffed grass. Elephant Grass was loaded onto the scale until a load of 3,000 pounds was reached. The grass was then fed into the chaffing machine until the load weight on the scale fell to 2,250 pounds, that is until one quarter of the charge had been ensiled. At this point chaffing was stopped and a 25 pound sample of chaffed grass was collected from the silo. The method of collecting this sample was to complete the spreading and trampling of the quarter of the charge and then to collect double handfuls of chaff at random over the surface until a weight of 25 pounds was obtained. The chaffing and filling was recommenced and continued until a second 750-pound portion of the charge was ensiled when the sampling was repeated. Altogether four 25-pound samples were collected to give 100 pounds representing the 3,000-pound charge. These four samples were bulked, thoroughly mixed and sampled by quartering. Ultimately 25 pounds was retained as the sample for the charge and 75 pounds returned to the silo.

With the repetition of the sampling procedure for each charge four 25-pound samples were collected as representative of each half-day's filling. The total 100 pounds was divided into two portions, after thorough mixing. One portion, of 40 pounds, was put in a plastic bag. The other portion, of 60 pounds, was taken to the laboratory for determination of dry matter content. The plastic bag was buried in the chaffed grass, care being taken to place it about twelve inches deep and to have it lying as flat as possible with its contents evenly distributed within it. The final addition of molasses was not made until the plastic bag was in position.

The ensiling was begun on the 20th of November, 1945, and completed on the 24th. The silo was opened during the last week of April in readiness for the feeding trial which began on the 1st of May, 1946. As the silage was used the bags were removed, weighed and

taken to the laboratory for the determination of dry matter content.

The Feeding Trial

As is customary in this type of investigation we used the Double Reversal technique in the feeding trial. The treatment of the two groups of cattle is given in Table 1. Period 1 extended from the 1st May to the 31st of May inclusive. Period 2 extended from the 1st of June to the 30th of June inclusive. Period 3 extended from the 1st of July to the 25th of July inclusive. Changes from fresh grass to silage and *vice versa* were made gradually over an interval of four days. Thus in changing from grass to silage in Group A one quarter of the grass allowance was replaced by silage on the 30th May, half was replaced by silage on the 31st of May and three-quarters was replaced on the 1st of June. On the 2nd of June full silage feeding was begun. The same procedure was adopted in all changes.

TABLE 1

Double Reversal Feeding Trial for Comparing the Nutritive Values of Freshly-cut Elephant Grass and Ensiled Elephant Grass

GROUP	No. of Cows	Period 1	Period 2	Period 3
A	12	On Grass	On Silage	On Grass
B	12	On Silage	On Grass	On Silage

Twenty-four cows were used. They were Holstein-Zebu crossbreds, of predominantly Holstein ancestry. They were selected from the Government Stock Farm milking herd and were in the earlier stages of lactation.

No grazing was allowed during the experiment. The cows were confined to the byre except during a daily exercise period of two hours in a bare yard. The daily routine of management is given in Table 2.

TABLE 2

Daily Routine of Management of Experimental Cattle

6.00 a.m.	Two-fifths of concentrate ration fed.
7.00 a.m.	Milking.
8.00 a.m.	Exercise in gravelled stockyard.
10.00 a.m.	Return to byre and given appropriate roughage in mangers.
11.30 a.m.	Mangers cleaned and one-fifth of concentrate ration fed.
12.00 noon	Appropriate roughage given in manger.
3.00 p.m.	Mangers cleaned and two-fifths of concentrate ration fed.
4.00 p.m.	Milking.
5.30 p.m.	Appropriate roughage given in manger.

The concentrate allowance was regulated according to milk yield. Each animal received a basic supplement of 2½ pounds of concentrates plus an additional supplement of 4 pounds of concentrate for each gallon of milk produced. The composition of the concentrate ration is given in Table 3.

TABLE 3

Composition of Concentrate Ration

Crushed maize	5
Coconut meal	20
Wheat bran	20
Soyabean meal	7
Pollards	25
Linseed oilmeal	20
Ground limestone	1
Salt	2

The silage was drawn daily from the silo. The fresh Elephant Grass was cut daily from plots irrigated by run-off liquor and washings from the byre and dairy. It was rich green in colour and in appearance was superior to most stands of Elephant Grass in Trinidad. The fresh roughage was chaffed to 1 to 2 inch lengths.

In addition each group received an allowance of 3 to 5 gallons of molasses daily. The molasses was poured over the roughage in the manger to encourage the animals to consume maximal amounts of both fresh and ensiled grass.

The same attendants milked the animals throughout the study and all milk yields were recorded.

RESULTS

The Silage

The silo was opened after five months' storage. The silage was greenish brown in colour and had a pleasant acid odour. It was uniform in appearance throughout the mass. No surface spoilage occurred during emptying of the silo and no spoilt silage was found in the main mass of the silage.

A point of considerable interest was the degree of consolidation of the silage. Although settling had occurred it was only slight in amount. The silage had not taken on the close texture as is found, for example, in maize silage and it was remarkably " springy " to walk on at all depths. On removing the cover it was found that little settling had taken place in the raised centre of the surface.

Wastage

On opening the silo it was found that the long Elephant Grass used as a seal under the board cover was completely rotted. The rotting also extended to a depth of about one inch over most of the upper surface. However, on approaching the wall of the silo the layer of rotted silage increased in depth until, at the wall surface the spoilage extended to a depth of 1 to 1½ feet. During the whole of the period of removal the material in contact with the wall was spoilt. It was impossible to say whether this spoilage occurred immediately after filling or whether it was occurring as air gained access during the removal of each day's layer of silage. If the latter cause was responsible the rotting was occurring at a depth considerably below the upper edge of the surface against the wall.

The plastic bags were recovered as the level of silage fell. They were in their original condition and showed no sign of deterioration.

TABLE 4

Dry Matter Content of Grass and Silage and the Fermentation Losses of Ensiling

Day	Sample	% Dry Matter in Fresh Grass	% Dry Matter in Silage	% Dry Matter Lost in Ensiling
1	a.m.	23.4	19.5	16.7
1	p.m.	29.4	26.5	9.9
2	a.m.	26.5	22.5	15.1
2	p.m.	29.9	25.9	13.4
3	a.m.	25.0	22.0	12.0
3	p.m.	30.9	30.3 *	1.9 *
4	a.m.	22.4	19.0	15.2
Average		26.8	22.6	13.7

* Excluded from averages.

In Table 4 the percentages of dry matter in each half-day's filling of chaffed grass are given. These values were obtained from the analysis of the 60-pound sample taken to the laboratory. In addition, the losses arising from respiration and fermentation are given; for brevity, those losses are referred to below simply as fermentation losses. These were determined by analysis of the material remaining in each plastic bag at the time of its removal from the silo. One aberrant value was obtained and has been excluded from calculation of averages. We are unable to explain this erratic result and its exclusion from calculation of average values increases, somewhat, our estimate of fermentation losses. In calculations for Tables 4 and 5 we have disregarded the small contribution made to the silo contents in the form of molasses.

In Table 5 an analysis of all wastage losses is given. Of the ensiled dry matter four-fifths was recovered in edible form. Of the total wastage, 21.2%, about one-third of it arose from surface spoilage and the remainder from fermentation losses.

TABLE 5

Wastage in Ensiling of Elephant Grass

	Dry Matter in Pounds
83,300 pounds of chaffed Elephant Grass of 26.8% average dry matter content	22,324
Fermentation wastage at 13.7% of dry matter	3,058
Total dry matter in silo at conclusion of ensiling process	19,266
7,401 pounds of spoilt silage at 22.6% dry matter	1,673
Total edible dry matter in silo	17,593
Percentage wastage caused by :	
a. Fermentation	13.7
b. Top and side spoilage	7.5
Total wastage from all causes	21.2

There was no effluent from the drainage vent at the base of the silo.

The Feeding Trial

Two animals, one in each group, fell ill during the course of the investigation and were removed from the experiment. The data given in Table 6 refer to the eleven animals remaining in each group. The values for milk production in each case represent the total outputs for the central 18 days of each period : the 8th to the 25th of May, the 8th to the 25th of June and the 8th to the 25th of July. These were the data used for statistical analysis.

In Group A the switch from grass during the first period to silage during the second was associated with a reduction of about 120 pounds in milk production. When Group B was changed from silage to fresh grass the reduction was about 41 pounds. After the second change in Group A, from silage to grass, a reduction of about 334 pounds in milk production occurred. The second change in Group B, from grass to silage, was associated with a reduction of about 626 pounds in milk production.

A statistical analysis of the data in Table 6 was made to test the difference in milk yields between the fresh grass and silage periods. The value of t was 2.503, which is significant at the 5% point. The feeding of silage reduced the milk yield below the grass feeding yield by $4.23 \pm 1.68\%$.

The consumption of fresh Elephant Grass averaged 51.3 pounds per head daily. The consumption of silage averaged 45.6 pounds per head daily.

TABLE 6

Milk Yields of Groups A and B Cattle

GROUP A			
Cow No.	Grass Period	Silage Period	Grass Period
1	222.75	196.00	198.25
2	264.75	239.50	225.00
3	261.00	221.00	206.00
4	216.25	185.00	199.00
5	455.00	530.25	428.50
6	228.00	210.50	175.50
7	230.50	237.75	187.00
8	286.00	276.50	237.50
9	320.00	293.00	250.50
10	267.25	276.00	223.00
12	281.00	246.75	248.25
Total	3032.50	2912.25	2578.50

GROUP B			
	Silage Period	Grass Period	Silage Period
13	230.00	217.50	144.75
14	284.25	286.50	209.00
15	216.00	223.50	182.00
16	396.25	397.00	314.00
17	286.50	293.00	224.50
19	262.50	226.00	139.00
20	310.50	297.00	219.75
21	229.00	218.00	178.00
22	228.50	230.00	182.50
23	263.50	281.75	235.25
24	191.00	187.00	202.00
Total	2898.00	2857.25	2230.75

Labour and Costings

The data for labour and costings are given in Table 7.

TABLE 7

Time and Labour Costs of Ensiling 84,000 Pounds of Elephant Grass

Date	Cutting Grass in Field			Cartage to Silo	
	No. of Cutters	Acreage Cut	Labour Cost	No. of Carts	Labour Cost
20.11.45	7	1.2	$ 5.25	3	$ 5.12
21.11.45	6	0.9	$ 4.50	3	$ 5.12
22.11.45	7	1.3	$ 5.25	3	$ 5.20
24.11.45	5	0.6	$ 3.75	2	$ 3.60
Total	—	—	$18.75	—	$19.04

Weight of Grass Ensiled	Chaffing of Grass and Filling of Silo		
	Time	No. of Men	Labour Cost
24,000 lb.	8.20 a.m. to 6.00 p.m.	16	$ 23.42
24,000 lb.	8.45 a.m. to 5.30 p.m.	21	$ 28.46
24,000 lb.	8.55 a.m. to 5.00 p.m.	18	$ 24.62
12,000 lb.	8.50 a.m. to 11.45 a.m.	6	$ 8.88
84,000 lb.	—	—	$ 85.38

Total Operational Charges	
Cutting grass in field	$ 18.78
Cartage of grass to silo	$ 19.04
Chaffing grass and filling silo	$ 85.38
Mechanic's wages	$ 7.68
Fuel and Oil	$ 7.52
Total	$138.37

Of the items listed in the table the costs of grass-cutting, and fuel and oil represent a fair estimate of the expenditure which would be incurred under normal working conditions. The expenditure on cartage is somewhat above normal working costs because the carts were frequently kept standing in the yard owing to the general slowing down of operations by the sampling procedure. Under normal working conditions the grass could be piled near the chaffing machine with no stopping of cartage.

The heaviest labour expenditure was for chaffing and filling. Here the over-estimate of costs is greatest. The double handling of the grass caused by the need for weighing and the complete suspension of all operations thirty-two times during each day to permit sampling greatly increased labour requirements.

Discussion

The present results are in harmony with experience of ensiling grassland herbage in temperate zones. The observations and implications are in close agreement with those of comparable studies in Europe and North America.

The silage was similar in appearance to that prepared from temperate zone grasses except that it was a much coarser material and less firmly consolidated. It was eaten with rather less relish by the experimental animals than was the fresh Elephant Grass although the difference in dry matter consumption between the silage-fed and grass-fed animals was negligible. We did not make daily analyses of the freshly-cut grass but data collected at the College shew that Elephant Grass of about the age of that used in the present work contains about 20% dry matter. The silage, having been made from a more mature grass and in spite of fermentation losses, contained 22.6% dry matter. Thus the average daily intake of 51.3 pounds of fresh Elephant Grass represented a dry matter intake of 10.26 pounds daily while the average daily intake of 45.6 pounds of silage represented a dry matter intake of 10.31 pounds daily.

The losses from fermentation and spoilage amounted to about one-fifth of the ensiled dry

matter. This result is in accordance with expectation for large-scale ensiling. In Table 8 is given a summary of the data obtained by Watson (1939) from his studies at Jealott's Hill and from his survey of the literature. It will be noted that our average fermentation loss of 13.7% compares favourably with the experience of Watson and others.

Our result is also close to that reported by Paterson (1945) for studies of ensiling Elephant Grass on an experimental scale, namely, 12.2%.

TABLE 8

Percentage Losses of Dry Matter in Ensiling Grass in Silos. Data from Jealott's Hill (J. H.) and from The Literature (L.)

Method of Ensiling	Source	No. of Samples	% Loss of Dry Matter
Low temperature silage	J. H.	7	18.2
	L.	49	16.9
Molassed Silage	J. H.	7	16.1
	L.	12	14.1
A. I. V. Silage	J. H.	11	17.6
	L.	25	13.9
Other acid-made silages	J. H.	4	18.6
	L.	12	15.3
Silage made with whey	J. H.	4	17.7
	L.	6	16.1

Our spoilage losses were higher than would be found in good temperate zone practice. As was mentioned above, most of the spoilage occurred at the wall surface, and, as the upper surface of the silage was approached, extending further into the mass of the silage. It is likely that much of this loss might have been avoided had we known that settling in the centre was much less marked in Elephant Grass than in ensiled grassland herbage of temperate zones. This failure to settle prevented the full pressure of the board cover being exerted in that part of the surface near the silo wall. It would seem advisable, therefore, that when Elephant Grass is ensiled for the centre of the top surface to be less raised in the centre than is customary with roughages that settle and consolidate to a greater extent. Judging from the state of the silage at most of the upper surface, and particularly towards the centre of the surface, a layer of long Elephant Grass with a close-fitting board cover and adequate weighting seems to provide a satisfactory method of sealing the silo.

The loss of dry matter during ensiling is an indication of the extent to which control of the fermentation processes have been brought under control by the adoption of correct methods of operation. It is an imperfect guide for assessing the extent to which nutritive value has been impaired. The only means of measuring the influence of any process on nutritive value is by carrying out a feeding trial and it was for this purpose that the experiment with the dairy cows was undertaken. Watson (1939), summarising the results of a large number of experiments on ensiling grassland herbage, using molasses, found that while the average loss of dry matter was 13.7% the loss of nutritionally available energy, as Starch Equivalent, was 22.7%. On the other hand the loss of digestible protein was only 7.8%.

The result of our feeding trial is in agreement with this generalisation. Both grass-fed and silage-fed animals consumed practically the same amount of dry matter from roughage. The slight adverse effect on milk yield — a depression of approximately 4% in the silage periods — indicates a lower feeding value in the case of the silage dry matter. It seems probable that the total silage rations provided inadequate supplies of available energy to meet the requirements for maintenance and milk production.

As stated above, the study of costings was not entirely satisfactory although the data obtained may serve as a guide in future work. The most serious over-estimation arose in the case of the chaffing and filling operation. Here our labour force averaged about 18 men. So large a number was required so that rapid chaffing and filling between samplings could be attained and the ensiling of 24,000 pounds each day completed. Under normal working conditions six men would have been required, two for chaffing, two for spreading within the silo and two for trampling. This reduction in labour, together with more expeditious carting, would reduce the cost of ensiling 84,000 pounds of Elephant Grass to about eighty dollars.

The present findings apply to circumstances where Elephant Grass is grown as a fodder grass and where the low rate of growth during the dry season raises the problem of supplying sufficient roughage at that time. The results indicate that Elephant Grass can be ensiled under tropical conditions with fermentation losses no greater than those commonly associated with the process. Spoilage losses were greater than usually observed under temperate zone conditions but they can probably be reduced materially. The silage is eaten in amounts comparable with fresh grass. The nutritive value is somewhat less than that of fresh Elephant Grass. Under practical conditions where it is unlikely that the animals would be restricted exclusively to silage the small deficit observed in nutritive value would be of little, if any, significance. The cost of the process is not high. Where a chaffed roughage, such as Uba Cane, is fed during the dry season cutting, carting and chaffing must be undertaken as a daily task. Indeed it may well be that the overall cost of ensiling several months supply of roughage in a single operation lasting several days would be less than the accumulated cost of daily collection and chaffing.

Summary

A description of ensiling Elephant Grass (*Pennisetum purpureum*) is given.

Respiration and fermentation losses were 13.7%. Spoilage losses were 7.5%.

A feeding trial with tropical dairy cows to determine the nutritive value of the silage for milk production, as compared with fresh Elephant Grass grown under irrigation, indicated a small reduction in feeding value. The milk production was significantly reduced by $4.23 \pm 1.68\%$.

Acknowledgments

The present investigation was part of a conjoint programme of research on the feeding of tropical dairy cattle undertaken by the Department of Agriculture of Trinidad and the Imperial College of Tropical Agriculture. The authors wish to acknowledge their indebtedness for the many facilities provided. They also wish to express their appreciation for the assistance given by Mr. E. H. Achong throughout the investigation, and to Mr. M. H. Quenouille for help with the statistical analysis of the feeding trial data.

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WITCHES' BROOM DISEASE OF CACAO IN GRENADA

The presence of witches' broom disease of cacao (*Marasmius perniciosus* Stahel) in Grenada was confirmed in October, 1948. A subsequent survey showed the disease to be widespread in all parishes, being severe in small areas at high or medium altitudes and scattered throughout the main cacao-growing districts as patches of medium and light infection or isolated affected trees. In severely diseased areas the incidence equals anything to be seen in Trinidad and the fungus shows an alarming tendency to produce sporophores all the year round. Other areas, at present uninfected, also appear suitable for rapid multiplication of the disease, which is already too well established for eradication to be a practical possibility. Control, by the elimination of infective material, is based on the knowledge that a period of 3 – 6 months must elapse between the appearance of "brooms" and their initial development of sporophores. In theory, if all diseased material could be destroyed before sporulation the disease would be eradicated; in practice, this is impossible, though much can be done to reduce its incidence and check spread to new areas. The following control policy, covered where necessary by appropriate proclamations under the Plant Protection Ordinance, has been adopted by the Grenada Government :

(1) Felling of groups of trees with high average infection, and destruction of all infected material, in areas particularly favourable to the disease, where its continuous rapid multiplication is to be expected. Replanting of cacao in such areas is prohibited.

(2) Pollarding of medium or heavily-infected trees, with destruction of infected material, in areas suitable for cacao cultivation, but for the necessary replanting of which no plants are immediately available. This involves cutting back the trees to their primary branches. It is the only feasible means of eliminating infections when at all numerous in old closely-planted fields like many in Grenada, where height of trees and closeness of canopy render removal of individual "brooms" a practical impossibility.

(3) Removal and destruction of "brooms" and infected pods in areas of light infection.

(4) Elimination of all cacao above the 1,200 ft. contour, with compensation for uninfected trees, and prohibition of cacao planting at over 1,000 ft.; provided that this shall not apply to any Government-controlled organisation engaged in propagation or research.

(5) Encouragement for replanting old fields with high-yielding clonal material as quickly as possible. W. T. D.

THE FODDER GRASS CONSUMPTION OF TROPICAL DAIRY COWS

BY

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Herbage in its green, dried or ensiled form is the principal source of nutrients for ruminants and maned stock. In the United Kingdom approximately two-thirds of the total energy requirements and three-quarters of the total protein requirements of cattle, horses and sheep are supplied in these forms. Herbage, and in particular grazed herbage, is also the cheapest source of nutrients for these classes of stock. Only in exceptional circumstances can protein and energy be provided more cheaply in the form of concentrates.

The nutritive value of temperate zone herbage varies throughout the year according to the stage of growth, the highest values occurring during the spring flush and the lowest during late autumn and winter. During the period of spring growth the dairy cow grazing on good pasture under adequate management consumes sufficient grass of such quality that the energy content is great enough to meet her maintenance needs together with the energy requirements for producing between four and five gallons of milk. But because such grazings are disproportionately rich in protein as compared with energy the daily intake of protein is more than sufficient to meet the protein requirements for a production of four to five gallons of milk. In the case of high yielding cows the only additional feeding necessary is the provision of a cheap carbohydrate supplement to remedy the shortage of energy.

The difficulty of providing tropical dairy cows with an adequate supply of green herbage of good nutritive value is widely recognised as being one of the main obstacles to the economic production of milk in many parts of the tropics. The protein and energy values of some common West Indian roughages are given in Table 1. Data for U.K. pasturage are included for purposes of camparison.

The West Indian roughages are strikingly inferior to U.K. pasture grass, particularly in the case of pastures rotationally grazed. In the case of extensively grazed pastures the difference is less marked. Observation of dairy herds in Trinidad, and in particular of a small herd maintained for a period at the Imperial College, indicated that the degree of supplementary feeding necessary was much greater than would have been expected from the differences in roughage composition. In no case was the herd maintained on fodder grass as the sole roughage, grazing being allowed in all cases. The question arose whether the quantities of fodder grass consumed were comparable with the quantities of roughage eaten by temperate zone stock.

This aspect does not appear to have been studied in tropical dairy stock, although em-

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TABLE I: NUTRITIVE VALUE OF ROUGHAGES

Roughage	Dry Matter	Digestible Crude Protein	Starch Equivalent
	%	%	%
Elephant grass (*Pennisetum purpureum*)	19.8	0.9	8.1
Guatemala grass (*Tripsacum laxum*)	20.4	1.3	7.9
Uba cane (*Saccharum sinense*)	23.4	1.4	11.9
Bamboo grass (*Paspalum fasciculatum*)	20.8	0.6	7.7
Savannah grass (*Axonopus compressus*)	39.1	1.8	21.8
U.K. Pasture, close grazing :			
Rotational, with 3 weekly intervals.	20.0	3.7	14.6
Rotational, with 4 weekly intervals.	20.0	2.6	13.4
U.K. Pasture, extensive grazing :			
Average over the year.	20.0	2.2	11.3

Recalculated from Harrison, E. *Tropical Agriculture* (1942), *19*, 147.

phasis is placed on the importance in the future of stall-feeding such animals with fodder grass. Temperate zone dairy cows freely consume a hundred to a hundred and fifty pounds of grass daily, or its equivalent as hay and silage. Failure on the part of the tropical milch cow to consume comparable amounts of fodder grass would aggravate still further the inadequacy of this type of roughage to provide protein and energy. The statement made by Harrison (1942) that the animals used in his digestibility trials showed a low dry matter consumption (1.6 pounds dry matter per 100 pounds liveweight) appears to be the only recorded observation in this connection.

Source of Data

The data used in the present analysis are derived from those given in the preceding communication by McWilliam and Duckworth concerning the preparation of Elephant Grass silage and its nutritive value for tropical dairy cattle in milk. While the primary purpose of the study was to compare ensiled with fresh Elephant Grass the secondary purpose was to collect data on fodder grass consumption as a means of verifying the observations made at the College on roughage consumption.

As the animals were restricted solely to fresh Elephant Grass and Elephant Grass silage for a period of three months they provide the only available data for fodder grass, or silage, consumption uncomplicated by grazing. Indeed they represent the extreme case of dairy cattle being fed exclusively on fodder grass in the stall with no supplementary grazing.

The average consumption of fresh chaffed Elephant Grass was 51 pounds per head daily, or about 10.3 pounds of dry matter. The corresponding silage consumption was 46 pounds daily, or 10.3 pounds of dry matter.

Discussion

The roughage consumption both as freshly chaffed Elephant Grass and silage was low as compared with the roughage intakes of temperate zone cows. The intakes of dry matter were the same in silage-fed and grass-fed cattle.

Table 2

Average daily intake of nutrients by cows restricted to Elephant Grass as a source of roughage compared with estimated daily requirements

Feedingstuff	Amount Consumed	Dry Matter	Starch Equivalent	Digestible Crude Protein
	lb.	lb.	lb.	lb.
Elephant Grass	51	10.3	4.1	0.46
Concentrates	8.1	7.3	5.0	1.31
Molasses	3	2.2	1.5	—
	Total	19.8	10.6	1.77
Estimated daily requirement of cow of 825 pounds liveweight yielding 14 pounds of milk daily		25.0	9.1	1.43

In Table 2 is given the analysis for dry matter, Starch Equivalent and digestible crude protein of the average daily ration of the cows receiving chaffed grass in the silage experiment. The average liveweight of the cows was 825 pounds and the average milk production about 14 pounds daily. Examination of the data presented indicates that the amount of Elephant Grass eaten provided half the daily intake of dry matter, about two-fifths of the daily supply of energy and about one-quarter of the daily supply of digestible crude protein. The estimated daily requirements given in the Table are based on temperate zone rationing standards for dairy cattle.

Feeding standards have not yet been worked out for tropical dairy cattle but it is unlikely that they differ markedly from standards already established for temperate zone animals. The rationing system used in the study reported in the preceding communication by McWilliam and Duckworth is based on the experience gained at the Government Stock Farm with cross-bred types of dairy cattle receiving Elephant Grass, or Uba Cane, and Savannah Grass *(Axonopus compressus)* grazing. It will be noted that intakes of energy and protein are close to, but somewhat higher than, the temperate zone standards. In practice, under temperate zone conditions, it is customary to feed rather more

than the standards demand in order to provide a margin of safety for individual variation in cattle. Consequently there is little difference in practice between the supplies of nutrients provided to milking stock in the two zones.

Strikingly different, however, is the roughage contribution to the daily requirements of nutrients in the two zones. This comparison is made in Table 3. The deficit of energy and protein in the case of the tropical cow restricted to fodder grass makes a sharp contrast with the excess supplies of nutrients gained by the temperate zone cow eating larger quantities of a roughage of higher nutritional value.

TABLE 3

Comparison of roughage contributions to daily nutrient requirements of Trinidad and temperate zone dairy cows.

Animal	Starch Equivalent	Digestible Crude Protein
	lb.	lb.
Trinidad cow consuming 51 lb. Elephant Grass	4.1	0.46
Requirements for Maintenance + 14 lb. Milk	9.1	1.43
Deficit	5.0	0.97
U.K. cow consuming 100 lb. pasture grass	11.3	2.20
Requirements for Maintenance + 14 lb. Milk	9.1	1.43
Excess	2.2	0.77

The present results show that the emphasis that has been placed on the low nutritive value of tropical roughage hitherto has led to the quantitative aspect of the problem of feeding tropical dairy cattle being neglected. It is unlikely that the low consumption noted in the case of cattle consuming Elephant Grass is a peculiarity of this roughage alone. The observations of a number of workers at the Imperial College, summarised in Harrison's report, are of the same order: the average daily consumption of dry matter in the form of roughage was 1.6 pounds per 100 pounds liveweight for a wide range of roughages. This is equivalent to a daily intake of about 66 pounds of fresh roughage for cows of 825 pounds liveweight. As would be expected the value is somewhat higher than that noted in the silage experiment. The data cited by Harrison were obtained in digestibility trial studies in which roughage alone was fed to animals of, principally, the draft type. In milking cattle the obligatory feeding of concentrates reduces the space available in the rumen for the roughage component of the day's ration.

The present case of low roughage consumption is essentially a problem of rumen capacity. Although the estimates of different workers vary the majority consider that a daily intake of 2.5 to 3.0 pounds of dry matter per 100 pounds liveweight represents a safe limit in the case of dairy cattle in milk. Others believe that intakes as high as 3.5 pounds of dry matter per 100 pounds liveweight do not necessarily overtax the rumen nor lead to deleterious effects on the health of the cow. The daily intake of 19.8 pounds of dry matter in the present case, equivalent to 2.4 pounds per 100 pounds liveweight, is below these estimates of rumen capacity.

There appear to be three possible explanations for the low roughage consumptions noted in the present study and in past digestibility trials at the College. First, it may be that the volume of the rumen, when normally distended, is less in tropical stock than in temperate zone animals. Second, it may be that the types of roughage studied do not collapse and form a compact mass within the rumen but instead maintain their bulky form during much of the process of digestion; in such a case the rumen would be distended to the normal degree with relatively low quantities of roughage. Third, it may be that digestion in the rumen proceeds less rapidly in stock-fed material of the type of Elephant Grass than is the case in stock consuming the finer leafed herbages of temperate zones; a slower rate of digestion leading to a slower rate of evacuation of the rumen could only lead to a lower daily intake of roughage.

Of these three explanations the first, that of inferior rumen capacity, appears to be the least likely to account for the difference observed. No worker with tropical stock has reported reduction in rumen size sufficient to account for roughage consumption of only half of those observed in temperate zone stock.

It is difficult to differentiate between the two remaining possible causes, the failure of Elephant Grass to form a compact mass within the

rumen and a slow process of digestion of Elephant Grass by micro-organisms in the rumen. Indeed it is to be expected that both causes operate and that they are intimately interrelated. Adequately to investigate the problem would require a study of the digestion of tropical roughages using animals with fistulae and with periodic examination of rumen contents during the process of disintegration of the roughage. That the course of digestion of tropical roughage is different from that of temperate zone roughage has already been shown (Duckworth, 1946).

The present results indicate that Elephant Grass is an unsatisfactory roughage for dairy cattle in milk. Owing to its inferior nutrition value and the low level of consumption, heavy feeding of supplementary concentrates is necessary. The concentrate portion of the ration occupying a part of the rumen capacity further reduces the space available for roughage. The overall effect is that where cattle of the present type are fed on Elephant Grass alone as the source of roughage the daily requirement for concentrates is about 5 pounds, on the average, for each gallon of milk produced. In the case of cattle of lower milk production and with access to grazing, particularly of fine-leafed herbage, the concentrate allowance per gallon of milk produced is materially less.

In view of the unsatisfactory nature of Elephant Grass, and probably of other similar roughages, as a source of nutrients for milking cattle it seems advisable to consider other forms of roughage for stall-feeding. In this connection it is likely that ensiled leguminous crops may be of value. Previous experimental scale studies at the College have indicated that a wide range of crops, including certain legumes can be ensiled under tropical conditions. In the preceding communication McWilliam and Duckworth have shown that losses are no greater, in farm-scale operations, than occur in temperate zones. Leguminous silages have a relatively high protein content: Velvet Bean contains 2.7% digestible crude protein, Soya-bean and Woolly Pyrrol 2.6% and cowpea silage 1.8%. The values are considerably higher than in Elephant Grass where the digestible protein content is about 1%. Such silages are readily eaten by milking stock. It is usual to feed 30 to 50 pounds of silage together with other roughages but in many cases quantities greater than these have been fed for long periods without deleterious effects, provided the silage was of good quality. A consumption of 50 pounds of the leguminous silages given above will provide the digestible crude protein necessary for maintenance together with about one gallon of milk production. The growing of these leguminous crops for ensiling presents little difficulty under tropical conditions and, where crop growth exceeds silage requirements, the crop can be allowed to ripen, the seed used in concentrate rations and the crop residues used in composting.

Summary

The daily consumption of Elephant Grass, both fresh and ensiled, was determined for tropical dairy cattle in milk. The average consumption of fresh grass was 51 pounds and of silage was 46 pounds. These amounts are about half of those normally consumed by cattle consuming temperate zone herbage.

The implications of this low consumption of roughage of low nutritive value was discussed. It was suggested that attention be given to the use of an ensiled legume crop as a source of roughage for stall-fed milking cattle.

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ERRATA

Due to a printer's error in the article *A Preliminary Investigation Into Nitrification in British Guiana Sugar-Cane Soils*, by F. Hardy and C. W. Hewitt, appearing on page 38, Vol. XXV, Nos. 1-12, the second line of paragraph 3 should be transposed with the second line of paragraph 5.

THE EFFECTS OF CERTAIN CROP ROTATIONS ON THE INCIDENCE OF BACTERIAL WILT DISEASE (XANTHOMONAS SOLANACEARUM) OF TOMATO

BY

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Bacterial wilt disease *(Xanthomonas solanacearum)* has long been recognised as a cause of losses in Trinidad tomato cultivation. Briant (1) suggested crop rotation as a method for control, but he indicated that it would be advisable to avoid tomato, or other susceptible crops, for three to four years. This seems to have been a " counsel of perfection " and there has been little or no conscious attempt to practise the advice then given, because growers are reluctant to restrict their tomato cultivations, as long as remunerative crops can be obtained periodically, in spite of wilt disease. Therefore, it appeared desirable to determine whether any degree of control could be obtained by avoiding susceptible crops for comparatively short periods. This paper describes an attempt to study such aspects of the problem.

Methods

About one-fifteenth of an acre at the St. Augustine Experiment Station of the Trinidad Department of Agriculture was used for the experiments now to be described. This site had carried a variety of field crops for a number of years before the experiment began, and a crop of tomatoes immediately preceded the start of the experiment. This piece of land was divided into three equal areas, the boundary positions of which were precisely and permanently marked. In each of these three sections, similar rotations were planted at intervals of about four months, thereby representing replications in time of the same crop rotations.

Within the limitations of the land available, it was not practicable to study the permutations of many different crops as experimental rotations. Therefore, it was decided that attention should be confined to three crops, namely, cauliflower, tomato and melongene (*Solanum Melongena*), the two latter being " susceptible " and the other " not susceptible " to *X. solanacearum*. These crops are commonly grown commercially, and could serve as possible components of improved market-garden rotations in Trinidad.

It was fully expected that different seasonal conditions would affect the results in an experiment of this nature, nevertheless it was considered desirable to include a range of seasons in the trials. To study time of planting effects precisely would have been beyond the scope of these experiments, but it was decided that some information on this aspect of the problem would be obtained by replicating the rotations over a period of time, thereby contrasting different planting seasons.

When the site of an experiment was idle before the initial planting was due, one or more crops of tomatoes were grown, to occupy the land in the meantime. In other respects, the whole area received the same cultivation treatments throughout the course of this trial.

Preliminary Trials of Rotations and Times of Planting

Each of the three areas was laid out as a randomized block (referred to later as Experiments A, B and C) in which nine rotation treatments were replicated three times. The plots were uniform in size and contained nine plants, spaced at 2′ x 2′.

The nine rotation treatments are shown in Table 1, where T = tomato ; M = melongene ; C = cauliflower.

TABLE 1

Crop Sequences and Order of Planting

Treatment	I	II	III	IV	V	VI	VII	VIII	IX
Order of planting									
1st stage	T	T	T	M	C	M	C	M	C
2nd stage	T	M	C	M	C	C	M	T	T
3rd stage	T	T	T	T	T	T	T	T	T

It is to be noted that the final crop (3rd stage) of each rotation is tomato. Table 2 shows the month of planting the three stages in each rotation and the month of reaping the final stage.

Results

The yields of produce from all the plots were observed throughout the trial and the numbers of individual tomato plants which succumbed to wilt, were also recorded. However, it is the results in the final tomato stage which are of greatest interest and importance, therefore

TABLE 2

Months of Planting and Reaping

Planting Month	March '45	July '45	Nov. '45	Apl. '46	July '46		Month of Reaping the Final Crop (3rd stage)
Experiment A	1st	2nd	3rd	stage			March '46
Experiment B		1st	2nd	3rd	stage		August '46
Experiment C			1st	2nd	3rd	stage	November '46

they alone will be considered now. Tables 3 and 4 show the numbers of wilted tomato plants and the yields of tomatoes at the final stage of the rotations.

Analyses of variance were carried out, but in none of the three experiments were "treatments" significant for either wilt or yields. It will be noted that the yields varied greatly in different seasons, being greatest in Experiment A, when the tomato crop was planted in November and reaped in March. Tomato yields were much smaller in Experiment B, when the crop was planted in April and reaped in July. Intermediate yields were obtained in Experiment C, when the tomatoes were planted in August and reaped in November. These results are in accordance with general experience.

The seasonal trends in rainfall are shown in Table 5, they are such that November is generally a favourable month for planting, because rainfall decreases later, whilst April is unfavourable on account of excessive rainfall in succeeding months. It is possible that seasonal temperature changes may also be important, although the mean temperature variation is only 3.1°F., (4). It seems probable that seasonal variations in tomato crops are associated with rainfall trends rather than with temperature differences.

Tables 3 and 4 indicate that relatively high numbers for wilt were observed in the Experiment A in which the highest yields were obtained. The relationship was studied in detail by determining the correlation coefficients for plot yields and incidence of wilt for each experiment. It was found that yields and wilt were negatively and significantly correlated in the cases of Experiments A and C, but for Experiment B, there was an insignificant positive correlation. The explanation of this apparent anomaly would seem to lie in certain subsidiary observations which were made in the course of Experiment B, when it was noted that, in the final stage, a number of tomato plants failed to yield and finally succumbed without showing symptoms typical of bacterial wilt disease, therefore such plants were not recorded as having been affected with wilt. There was no opportunity at the time for investigating the cause of the failure of these plants, but it would seem that they may have been affected by one of the other wilt diseases, which, as indicated by Baker (3), may be associated with such excessively wet weather as was experienced during the growth of the particular crop. It should also be mentioned that a midge *(Contarinia lycopersici)* was noted by Briant (2) as causing considerable damage to tomato flowers, especially during the wet season. It is possible that this insect may

TABLE 3

Numbers of wilted tomato plants in the final stage of the crop sequences shown below. The totals represent three plots each containing nine tomato plants.

	Experiment	A	B	C	
Treatment	Crop Sequence	Nov.-Mar.	Apl.-July	Aug.-Nov.	Total
i	TTT	15	12	7	34
ii	TMT	16	13	10	39
iii	TCT	10	8	2	20
iv	MMT	21	9	5	35
v	CCT	14	1	5	20
vi	MCT	7	10	4	21
vii	CMT	19	10	7	36
viii	MTT	20	11	4	35
ix	CTT	20	7	7	34
	Total	142	81	51	274

TABLE 4

Yields (oz.) of tomatoes reaped in the final stage of the crop sequences shown below. The totals represent yields of three plots each containing nine plants.

Treatment	Experiment / Crop Sequence	A Nov.-Mar.	B Apl.-July	C Aug.-Nov.	Total
i	TTT	654	33	100	787
ii	TMT	574	81	108	763
iii	TCT	668	47	284	999
iv	MMT	552	42	110	704
v	CCT	576	66	370	1012
vi	MCT	615	65	316	996
vii	CMT	651	55	156	862
viii	MTT	473	20	266	759
ix	CTT	509	43	260	812
	Total	5272	452	1970	7694

TABLE 5

Monthly rainfall in inches at St. Augustine Experiment Station during the period of the rotation experiments.

Year	Jan.	Feb.	Mar.	Apl.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1945	0.4	0.8	1.4	4.2	5.3	9.2	5.6	8.5	12.2	6.2	7.2	3.0	64.0
1946	4.7	1.0	0.9	0.9	9.5	9.6	7.7	12.1	6.1	7.0	6.7	2.3	72.5

also have contributed to the comparative failure of the tomato crop in the case of Experiment B.

Final Rotation Experiment

It has been explained above, that treatment differences were not statistically significant in the time of planting Experiments A, B and C. Inspection of the results given in Table 3, suggests that there may have been less wilt in the five rotations which include cauliflower (Treatments III, V, VI, VII and IX) as compared with the remainder. Similarly, there are indications in Table 4 that higher yields were obtained in the cases of the same five treatments when cauliflower was included in the rotation. However on closer examination of these results it appears that the larger beneficial effects were obtained when cauliflower immediately preceded tomato in the rotation, as in treatments III, V and VI. Accordingly, a new experiment (D) was designed with the object of determining whether less wilt and higher yields were associated with the sequence of cauliflower and tomato as compared with successive tomato crops, or with the sequence of melongene and tomato.

Experiment D was laid out as a 3 x 3 Latin square, in order to eliminate, as far as possible, the effects of soil differences on yields and on the incidence of wilt, other than those which could be attributed to the effects of the previous crop. The three treatments to be compared were the same as rotations numbered (i), (ii) and (iii) in Tables 3 and 4, namely, using the same notation TTT, TMT and TCT. The months of planting and harvesting of the three rotation treatments are shown in Table 6.

TABLE 6

Months of planting and reaping for each of the three stages (1, 2 and 3) of Experiment D.

	Planting month	*Reaping month*
1st stage	November '45	March '46
2nd stage	April '46	July '46
3rd stage	August '46	November '46

In Experiment D, each plot contained 27 plants, spaced at 2' x 2'. The numbers of wilted plants and yields of tomatoes in stage 3, are given in Table 7.

TABLE 7

Numbers of wilted plants and yields in Experiment D. The totals represent three plots each containing 27 plants.

Treatment	Crop sequence	Wilted plants (no.)	Yield (oz.)
(iii)	TCT	20	1975
(i)	TTT	37	1296
(ii)	TMT	59	646
	Total	116	3917
Significant difference at 5% point		9	1299

Analyses of variance showed that "treatments" were highly significant ($P < 0.01$) in the cases of both wilt and yield. The numbers of wilted plants are significantly less for treatment (iii) as compared with (i) and (ii). The numbers of wilted plants in treatment (i) are significantly greater than those of (iii) and less than those of (ii). In the comparison of yields, treatment (iii) is significantly greater than treatment (ii) whilst (iii) and (i) are not significantly different. An analysis of covariance of wilt on yield was also carried out, but it was found that the regression and correlation coefficients were negative but not significant. Therefore, it appears that in this experiment, although there is in general an inverse proportionality between yield and wilt, nevertheless there are factors other than the presence or absence of wilt which determine yield. This result is in accordance with the inconsistence of data from Experiment B, as compared with Experiment A and C.

Conclusions

The results from Experiment D have confirmed the indications from the earlier experiments, which suggested that there was less wilt and a greater yield of tomatoes, when preceded by a cauliflower crop as opposed to melongene or successive crops of tomatoes. Further, it appears that when three successive crops are considered, of which the ultimate one is tomato, the effect of the first is negligible in comparison with that of the penultimate one.

Unfortunately, it cannot be claimed that anything approaching complete control of bacterial wilt disease can be achieved by such short rotations. There is evidence which suggests that *X solanacearum* is widely distributed in Trinidad soils, so much so that what is referred to as "new" land may not be entirely free from these bacteria. The supposition, therefore, is that the bacteria are maintained in the soil probably through weed hosts which are never likely to be entirely eliminated for a sufficiently long period under local tropical conditions. Therefore, unless some form of soil sterilisation can be practised on the field scale, there seems little hope for the elimination of bacterial wilt infection by conventional methods. However, it may be claimed from the experiments described above, that the incidence of bacterial wilt may be reduced and high yields obtained through practising a system of crop rotation in which cauliflower, and not melongene or tomato, precedes tomato. The plot yields were equivalent to about seven tons of tomato per acre, when cauliflower preceded tomato, as opposed to about two tons per acre when melongene preceded tomato. In the case of continuous tomato crops, the plot yields in the final stage were of the order of about five tons per acre.

A subsidiary trial, in which a number of different crops were grown and followed by tomato gave generally unsatisfactory results because the final tomato crop was a comparative failure through excessive rainfall. However, there were indications that either cabbage or cauliflower would be a satisfactory crop to precede tomato, but this result needs confirmation by further experiments.

It is noteworthy that melongene does not generally show symptoms of bacterial wilt in Trinidad, nevertheless its cultivation seems conducive to wilt in tomatoes. At the present time no rational explanation can be offered for the observation that there may be more wilt when tomato follows melongene as compared with successive tomato crops. It is recommended that neither melongene nor any other member of the family *Solanaceae* should immediately precede tomato, although it is not undesirable that a crop of melongene should be succeeded by cauliflower before the planting of tomatoes.

Observations on the succession of crops in local commercial gardens have shown that tomato is often planted after a crop of melongene without the incidence of wilt being particularly high in the tomato crop. It should be pointed out, though, that there is generally a period when the land is uncultivated, after the melongene crop, whilst in the experiments described above, the tomatoes were planted immediately after the melongene. A "fallow" period was included as one of the treatments in the subsidiary trial referred to above, but there was no indication that absence of a crop was beneficial in the reduction of wilt later, but this observation also should be confirmed by further experiments.

Summary

(1) A description is given of field experiments which were undertaken to study the effects of certain rotations on the incidence of the bacterial wilt disease of tomatoes.

(2) The three crops included in the experimental rotations were cauliflower, melongene (*Solanum Melongena*) and tomato.

(3) When yields and incidence of wilt in the ultimate tomato crop were considered, it was found that in the two cropping-seasons, out of the three considered, there was a negative and significant correlation between yield and incidence of wilt.

(4) When the rotation consisted of three stages, of which the final one was tomato, the nature of the crop at the penultimate stage was found to be important, rather than the crop at the first stage of the rotation.

(5) In a final experiment, it was established that there were higher yields and a lower incidence of wilt when cauliflower preceded tomato, as compared with tomato or melongene before tomato.

(6) It is recommended that neither tomato nor melongene nor other solanaceous crop should immediately precede tomato. When it is necessary to grow tomatoes on land which has already carried a solanaceous crop, then cauliflower should be interposed as the crop to precede tomatoes.

Acknowledgement

The writer wishes to express his gratitude to Mr. J. C. Muir, O.B.E., for his interest and advice in the preparation of this paper.

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REVIEW

SOIL PHYSICS, BY L. D. BAVER. *2nd Edition, 386 pp. $4.75. John Wiley & Sons Inc., 1948.*

The appearance of a second edition of Dr. Baver's "Soil Physics" is welcome. It is possibly the only book in the English language that deals so fully with a subject that must be appreciated as a whole to be appreciated at all. The new edition, which is 28 pages longer than its forerunner, is presented in a new, more modern, more compact, and incidentally more pleasing, format. Errors obvious in the first edition have been corrected, in particular the misplaced legends of Donat's curves (Chap. 6) and the reversed headings over Kopecky's figures (Chap. 7).

Possibly the most welcome addition to the text is an exposition of Schofield's concept of pF, a subject too lightly treated in the first edition. Indeed the whole chapter on soil-water relations has been expanded and clarified, and 23 new references have been added to it, almost one-half of all the new references in this edition. Chapter 3 now contains some electron micrographs of clay particles, those of kaolinite and halloysite being particularly fine; there is also a short discussion of the role of electron micrography in studies of clay particles. To Chapter 5 has been added a new section on the contribution of biological agencies to the genesis of soil structure, a section that ought to be read in conjunction with Chapter 7 of Dr. Jenny's "Factors of Soil Formation". The new material on runoff and erosion, and the two excellent photographs of raindrop-erosion effects that have been added to Chapter 10, will be particularly welcomed by those interested in Tropical soils. It seems unfortunate that in this chapter, the relation between erosion and the factors contributing to its magnitude (climate, topography, vegetation, soils, and humus activities) is expressed by the 'equation'

$$E = f\ (C, T, V, S, H)$$

As it is stated that "this equation can be descriptive only because of a lack of knowledge of the significance of the different variables, as well as the difficulty of expressing the variables in similar terms", the 'equation' can do no more than invest a vaguely understood interaction with the aura of a mathematical precision we are not yet entitled to ascribe to it. However, in a book notable for its generally excellent colligation of data, such small points will pass.

Perhaps the only real defect of the book is the English in which it is written. Sentences such as: "This is a ... field ... that will permit the soil microbiologist and the soil physicist to co-ordinate their respective knowledges with rather successful results" (p. 162), in which 'respective' is meaningless and 'rather' impossible, do make for turgid writing. Moreover the regular use of 'relationship' where 'relation' is meant becomes irritating after a time.

Yet despite its style the book admirably serves its purpose. It succeeds, as does no other book I know, in presenting soil as an understandable physico-chemical dynamic system. Dr. Baver is to be congratulated on his industry and skill in producing what may well become a classic. His book should be available not only to all soil physicists, but to everyone whose interests bear on that most fascinating of all natural products, soil.

H. L.

THE EFFECTS OF VARYING AMOUNTS OF ZEBU BLOOD ON THE ADAPTABILITY OF DAIRY CATTLE TO CONDITIONS IN JAMAICA

BY

J. W. Howe, Ph.D.

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One of the most important problems of dairy farming in the tropics is the development of a dairy animal capable of giving a large production of milk, yet possessing a resistance to tropical conditions. Raising pure-bred cattle of the northern breeds in the tropics is uneconomical owing to their inability to withstand climatic and disease conditions.

An attempt has been made in many tropical countries to overcome such conditions, by crossing the northern breeds of dairy cattle which possess production, with the Zebu breeds which possess resistance.

This study of records of the dairy herd at the Government Stock Farm, Hope, Jamaica, was an investigation as to how the varying amounts of Zebu blood affect the adaptability of dairy cattle to conditions there, and to determine, if possible, the optimum amount of Zebu blood necessary for production of milk and resistance to tropical conditions.

The climate of Jamaica is tropical, the temperature ranging from a mean minimum of 68 degrees F., to a mean maximum of 91 degrees F. The average rainfall varies from a minimum of 30 inches per year on the coastal plains, to nearly 200 inches per year in some of the high mountain areas. There are two well defined wet seasons, May and June, and September, October and November, the dry season being from December to March.

Because of the high atmospheric temperatures combined with the high rainfall, imported pure-bred cattle of the northern dairy breeds do not thrive in Jamaica, and even when born in the tropics, such pure-bred cattle show a lack of growth and development, although maintained on a high plane of nutrition.

The most common diseases found in cattle in Jamaica are anthrax, blackleg and pneumonia, the losses from the latter being especially high during the wet seasons.

The main tropical diseases are tick fever *(Piroplasmosis)* and gall sickness *(Anaplasmosis)*. Regular dipping of the cattle is necessary to control infestation from ticks.

In an attempt to produce a type of dairy animal suitable for tropical conditions, the Government Stock Farm at Hope, Jamaica, commenced in 1915 crossing northern breeds of dairy cattle with the Zebu, using the Nellore and Hissar breeds of Zebu for the purpose. Northern breeds used included Ayrshire, Brown Swiss, Red Poll, Guernsey, Holstein and Jersey. The three first mentioned breeds proved less suitable for crossing than the others and were discarded, only the Jersey, Guernsey and Holstein breeds being retained.

In 1921 a shipment of Sahiwal (Montgomery) cattle was received from India, and since that time the Sahiwal breed has been used exclusively as a source of Zebu blood in the cross-breeding work.

Literature

Information on the cross-breeding of dairy cattle in the tropics comes mainly from work done in Africa, Australia, the United States, India, and the West Indies.

Hammond (9) reporting on the Hope herd, points out that in the case of breeding for high milk production in the tropics, feed should not be a limiting factor. He found that degenerative changes take place in animals of the northern breeds raised under tropical conditions, such changes being indicated largely by the loss of quality and type.

Carneiro and Rhoad (3) found that pure-bred Holstein calves in the tropics, from imported dams, show a decrease in growth rate as compared with such calves under temperate conditions, the check in growth rate taking place after four months of age and being accentuated after six months of age. These workers (3) attribute the slow growth rate of the northern breeds to the inability of such breeds to withstand the climate, and to the restriction of food due to the inability of such animals to metabolize properly at high temperatures, sufficient food for a normal existence.

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Condensed from a thesis submitted to the Faculty of the Graduate College, Iowa State College, in partial fulfilment of the requirements for the degree of Doctor of Philosophy. The complete thesis is on file at the Iowa State College Library.

Bonsma (1) found that animals of the northern breeds ceased ruminating at atmospheric temperatures above 90 degrees F., and states that the rate of heat loss determines the metabolic level, which in turn influences growth rate, fertility and other important body functions.

Coat colour has an important influence on the adaptability of cattle to high temperatures. Bonsma and Pretorius (2), in tests with Jersey cattle of seven different shades of coat colour, found the light reflected from animals of different colours is directly correlated with the intensity of colour of coat. Riemerschmid and Elder (17) working with white Zulu, red Afrikander and black Aberdeen Angus found similar results. These workers found the Jersey breed to have the greatest tolerance to high atmospheric temperatures, and attribute this to the breed having been developed in a mild climate. Further, the small size of the Jersey and the large skin surface per unit of weight tends to prevent body temperature rising above normal, particularly where cooling of the body depends largely on the degree of radiation.

Harrison (10) states the heat resisting ability of the Jersey makes it a suitable breed for crossing with the Zebu. Forman (6), Metivier (16), French (7) and Hammond (9) found the Holstein suitable for crossing. Hammond (9) however states that while the Holstein x Zebu produced more milk, the Jersey x Zebu might prove more suitable for general dairy conditions, owing to its greater ability to withstand high atmospheric temperatures.

Cousins (4) found the Hissar breed of Zebu unsuitable for dairy purposes because of their nervous temperament and low production, while the Nellore when crossed with northern dairy breeds produces animals which were slow maturing and low in production. Of the three Zebu breeds tried for cross-breeding purposes in Jamaica, the Sahiwal proved to be the most suitable.

Evidence that the Zebu breeds are immune to tick fever is lacking, although work done by Schmidt and cited by Kelley (11) indicates that Zebu cattle, while not immune to tick fever, have a high resistance to the disease.

As to the optimum amount of Zebu blood necessary for combined resistance and production, opinions vary. Matson (15) found half-breds satisfactory for conditions in India. Ducloux (5) states that 40% Zebu blood is necessary for conditions in Tunisia, while Harrison (10) and Metivier (16) found 25% Zebu blood sufficient to give the necessary resistance to conditions in Trinidad.

Source of Data

The data used in this study were taken from the records of the dairy herd at the Government Stock Farm, Hope, Jamaica, and cover the period 1910-1940 inclusive. The northern breeds included in the data are Jersey, Guernsey and Holstein, while the Zebu breeds are represented largely by the Sahiwal, a few animals of the Nellore breed are included. Records for pure-bred Jerseys and Guernseys are included in the study. No records on pure-bred Holsteins were available.

Classification of Animals According to Breeding

The animals were first classified by breed according to (1) the amount of northern blood, and (2) the amount of Zebu blood, the classification being that justified by Lush (14).

To study the effects of varying amounts of Zebu blood in the northern breeds on factors connected with production and adaptability, the animals were divided into groups according to the amount of Zebu blood they carried, each group varying by a fraction of one-eighth northern blood. The groups were numbered I to V, and varied from those which were pure-breds of the northern breeds and carried no Zebu blood (Group I), to animals which carried one-half Zebu blood (Group V). In all instances the amount of northern blood possessed by the animals is as set out in the various groups. All the animals listed which were not pure-bred contained some Zebu blood.

The method used for grouping the cattle for comparison is shown in Table 1.

Table 1. Method of Grouping Cattle for Comparison

Group	Amounts of Northern Blood		
	By eighths	By sixteenths	
I	8/8	16/16	Pure-breds
II	7/8	15/16 14/16 13/16	Seven-eighths breds
III	6/8	12/16	Three-quarter breds
IV	5/8	11/16 10/16 9/16	Five-eighths breds
V	4/8	8/16	Half-breds

Adjustment of Data

Lactations were first corrected for length from the regression equation evolved from these data themselves. The equation was, $Y = 842.9 + (10.28L.P.)$, where Y = estimated yield of milk in pounds, and L.P. = length of lactation period in days.

FIG. 1. Three-quarters Sahiwal, One-quarter Jersey.

FIG. 2. Jersey x Sahiwal Crossbred.

G. 3. *Left.* Jersey x Sahiwal Crossbred.
Right. One-quarter Sahiwal, Three-quarters Jersey.

FIG. 4. Pure-bred Jersey Bulls bred in Jamaica.

FIG. 5. Guernsey x Sahiwal Crossbred.

FIG. 6. Three-quarters Guernsey, One-quarter Sahiwal.

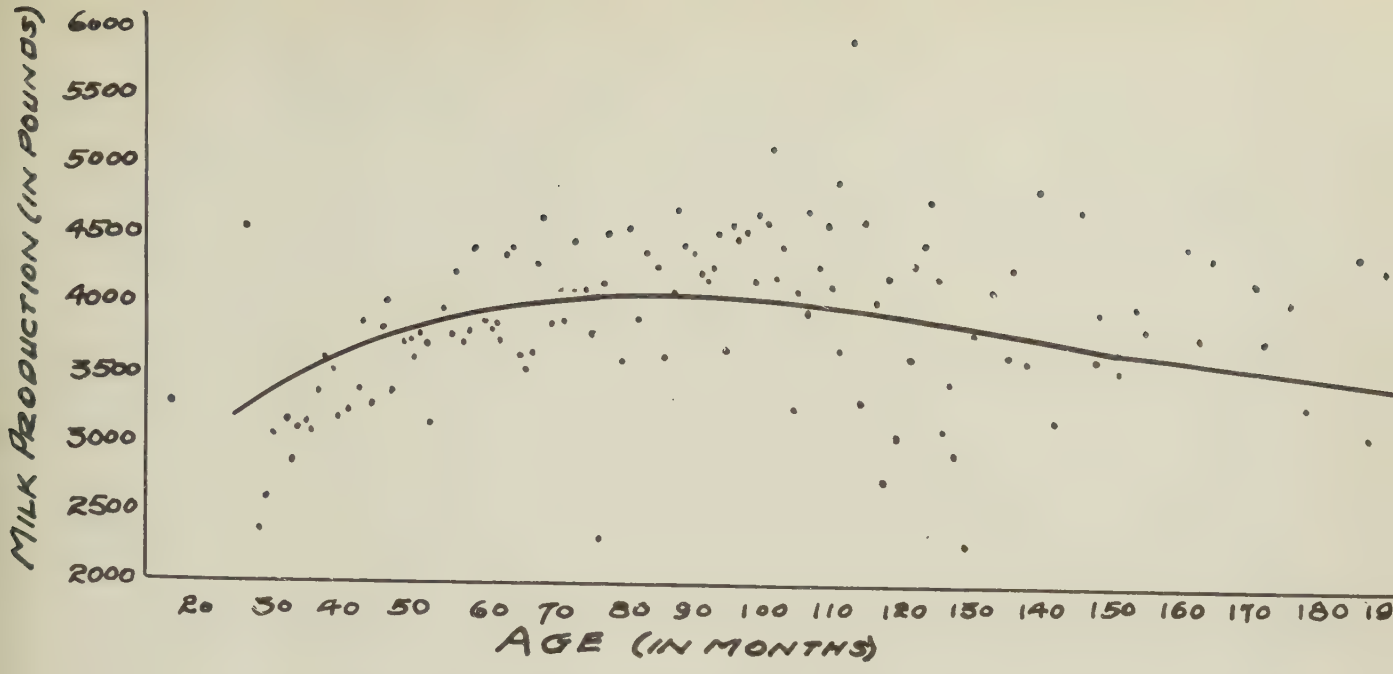

FIG. 7. MILK PRODUCTION BY AGE
JERSEY BREED

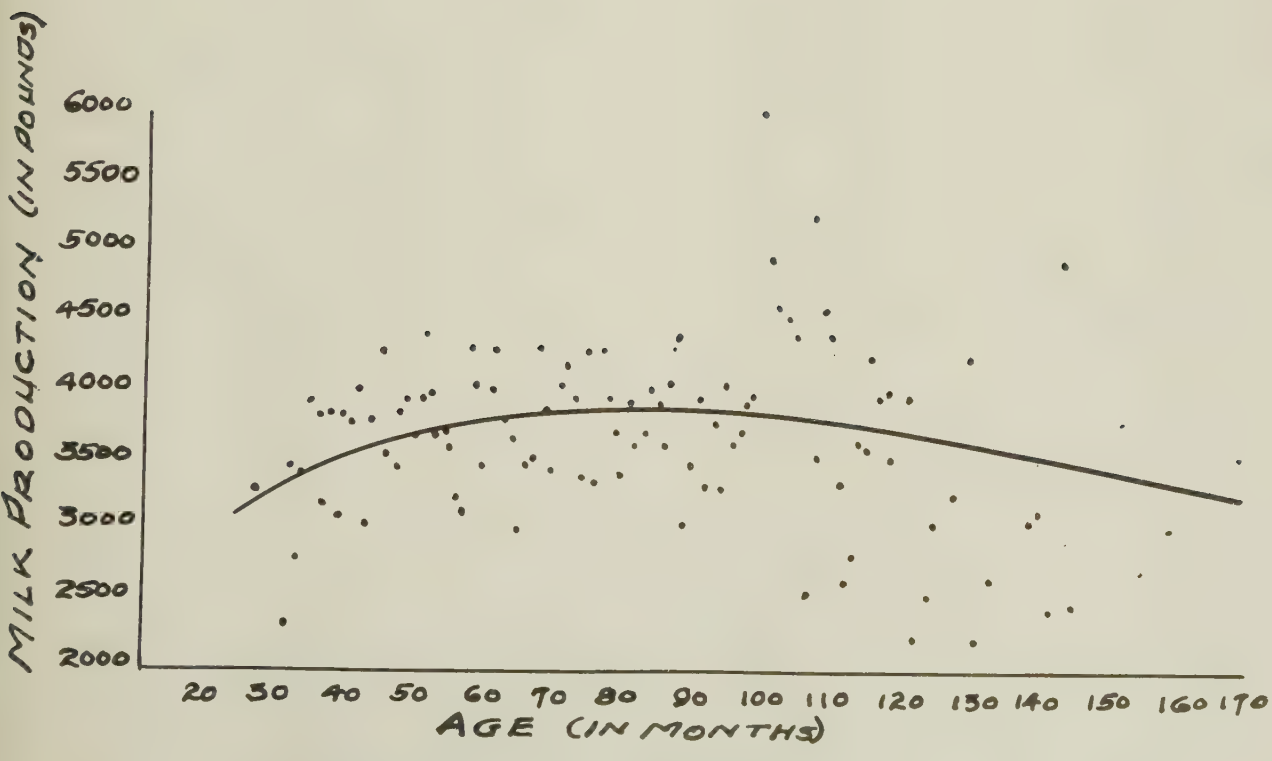

FIG. 8. MILK PRODUCTION BY AGE
GUERNSEY BREED

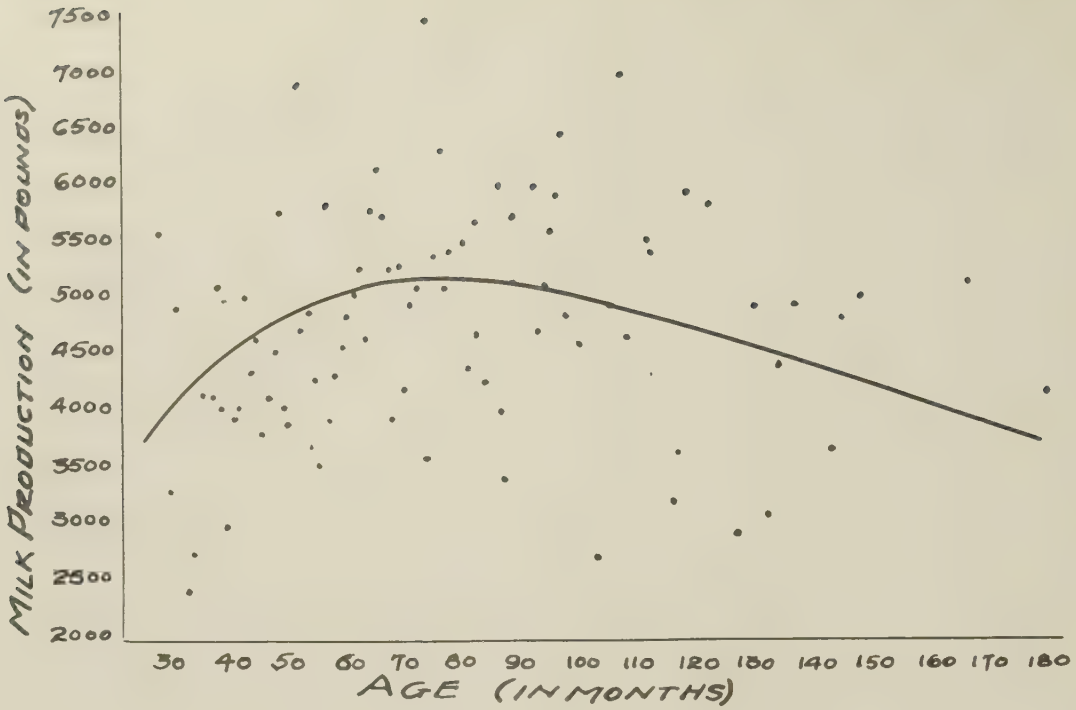

FIG. 9. MILK PRODUCTION BY AGE
HOLSTEIN BREED

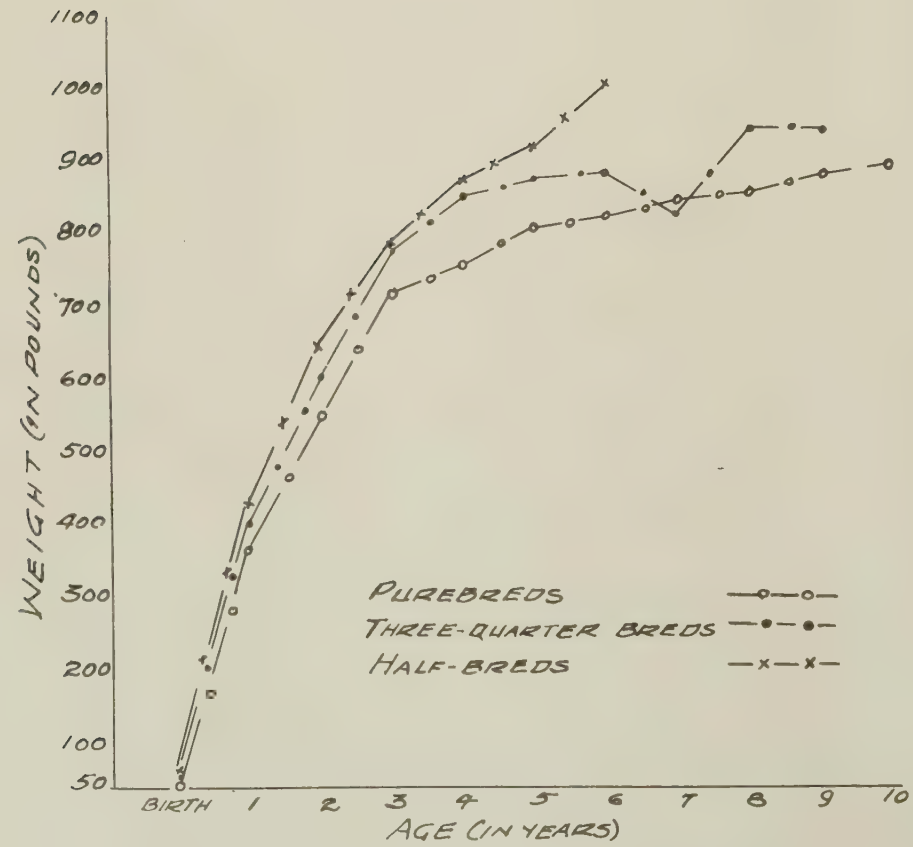

FIG. 10. GROWTH RATE OF PUREBRED
JERSEYS AND GUERNSEYS
AND SAHIWAL CROSSBREDS

After correcting each lactation for length, each lactation was then corrected for age, the correction factors used being those recommended for the various breeds, by the Bureau of Dairy Industry of the United States Department of Agriculture (12). The average corrected production of the various breeds used in the data is shown in Figures 7, 8 and 9. Each dot represents the average of the lactation records for particular age. The curve was considered to fit sufficiently well, that the correction factors would be as valid as any which could be derived from the data.

To compare the effects of varying amounts of Zebu blood on each of the factors studied, the averages for each factor were calculated for the various groups within each breed, as well as the average for the whole breed, together with the standard error.

An analysis of variance, as described by Snedecor (18) was carried out for each factor and the F-test was employed to test significance between the variances between and within groups in each case. A chi-square test was used to determine whether the sex ratio of calves dropped differed significantly, from the ratio of 1 : 1, as well as from the actual ration of males to females in the total of all calves dropped.

Results

Average Growth of Breed Groups

A comparison of the growth rate between pure-breds and cross-breds containing Zebu blood is represented graphically in Figure 10, while details as to the average growth rate of the various pure-breds and cross-breds are set out in Table 2.

Although the birth weight of the half-breds was higher than either the pure-breds or three-quarter breds, the increased growth rate of animals with Zebu blood over the pure-breds was more noticeable after two years of age. From the trend of the curve it would appear that animals with more than one-half Zebu blood would show an even greater increase in weight than either the pure-breds or three-quarter breds.

That the weight increase is more noticeable after two years can be attributed largely to the conditions under which the animals are raised. Up to about 18 months of age the animals are kept on a fairly high plane of nutrition, after which they are turned out on pasture and receive no additional feed unless the pasture is poor.

Table 2. Weights (in pounds) by Years of Pure-bred and Zebu Cross-bred Cattle

Age in Years	Groups I	II	III	IV	V
			Jersey		
Birth	51	50	54	55	61
1	367	334	326	386	445
2	550	535	532	586	653
3	717	715	672	765	774
4	745	761	783	848	875
5	799	761	809	869	850
6	806	825	792	885	1002
7	825	876	845	803	998
8	836	890	855	949	941
9	859	1006	905	926	990
10	862	792	803	921	955
11	904	860	803	666	924
12	982		803	588	1004
13	1036		804	788	1140
14					1210
15					1110
			Guernsey		
Birth	55	58	59	62	66
1	395	360	358	443	431
2	622	552	645	639	657
3	742	690	801	779	799
4	845	780	880	879	869
5	858	754	926	909	990
6	937	770	882	924	1008
7	927	854	1070	944	973
8	993		919	925	
9	1047		995	930	
10	1052			860	
11	1116				
12	1060				
13	1020				
1000					14
			Holstein		
Birth		66	69	68	70
1			403	300	390
2			667	584	610
3			798	831	808
4				986	924
5				1000	1030

Bonsma (1) has shown that the northern bred animals on pasture graze only about half as long as do the animals of Zebu breeding. Further, northern animals develop a higher body temperature under high atmospheric temperature conditions, which in turn causes a decrease in the efficient utilization of feed.

A logical explanation for the increase in growth rate of the animals with Zebu blood, is a combination of the two factors mentioned, which result in the Zebu animals making better growth because of their ability (1) to withstand climatic conditions, and (2) to use the available feed more efficiently.

Milk Production per Lactation

The average milk production per lactation of the various groups is shown in Table 3, while the analysis of variance for this factor is set out in Table 4. Production by breeds and groups is represented graphically in Figure 11.

Table 3. Average Production of Milk (in pounds) for 305 day Lactation

Breed	Groups I	II	III	IV	V	Breed Av.	Standard Error
Jersey	4,020	4,156	3,192	3,844	4,520	3,997	± 40
Guernsey	3,549	3,304	3,967	3,999	3,993	3,881	± 43
Holstein	—	3,740	5,104	4,878	5,506	5,142	± 106
Av. All Breeds	3,937	3,899	4,082	4,025	4,598		

Table 4. Analysis of Variance of Milk Production per Lactation

Breed		Degrees of Freedom	Mean Square	
Jersey	Within groups	577	912,362	
	Between groups	4	10,664,933	**
Guernsey	Within groups	342	630,266	
	Between groups	4	4,136,485	**
Holstein	Within groups	103	1,209,402	
	Between groups	3	4,050,176	*

The results show a significant or highly significant difference between all groups in all breeds as to milk production per lactation. It is possible that differences between years may have contributed to the difference between groups, since animals of the different groups which were included in the analysis were not always contemporary, especially during the earlier years of the experiment. After the first few years however, animals of each group were represented in each year's data. Since most of the data come from years in which all groups were represented, it seems unlikely that any difference between years can have had much effect on the differences between groups.

The general trend was an increase in production as the amount of Zebu blood increased, the highest production being made by animals with one-half Zebu blood. These animals were the result of crossing the pure-bred Zebu with pure-breds or high grades of the northern breeds, and, therefore, all the half-breds might be expected to show heterosis. No data are available for half-breds produced by other methods, such as crossing two half-breds together, or by crossing a three-eights with a five-eights. Theoretically, in such animals much less heterosis would be expected. The nature of the present data does not permit a clear cut separation between the effects of heterosis as such, and the varying amounts of Zebu blood.

The trend for production of all breeds appears on inspection to be linear from pure-bred to half-bred, the maximum production being reached by the half-breds. While the production in Group II of the Holsteins was below that of the other two breeds, there were only five animals in this group. If this group is disregarded, the trend for the Holsteins would be similar to that of the other two breeds.

From this study of data available, results indicate the most suitable cross to be the half-bred. As, however, no data were available on production of high grade or pure-bred Zebus, it was not possible to determine whether a higher proportion of Zebu blood than one-half would give a still higher milk production.

That the difference in production between the various blood groups is real, is indicated by the fact that the differences are highly significant in the Jersey and Guernsey breeds, the F-value being well above the level of probability. The differences in the groups in the Holstein breed were found to be significant but not highly so. From this it seems almost certain that these results would be repeated in a similar experiment. It is unlikely that such a marked difference could be due entirely to chance in sampling from a population in which there is no real difference.

The pronounced rise in production by the half-breds may be due to either or both of two factors; (1) greater ability of the animals with the higher amount of Zebu blood to withstand conditions in Jamaica, and (2) heterosis, resulting from the crossing of two genetically different types.

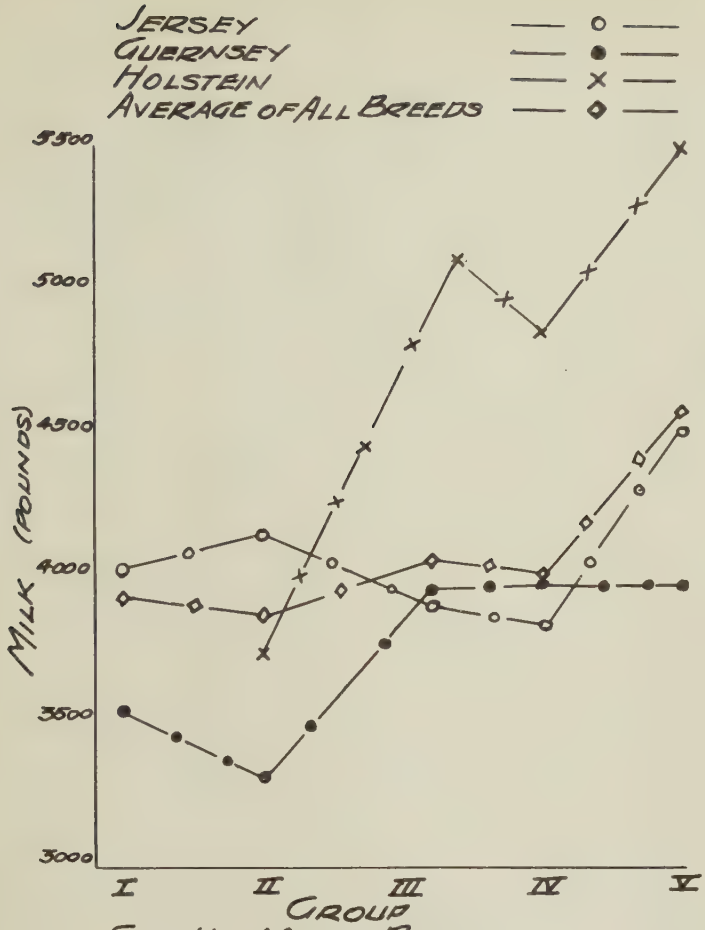

FIG. 11. MILK PRODUCTION FOR 305 DAY LACTATION

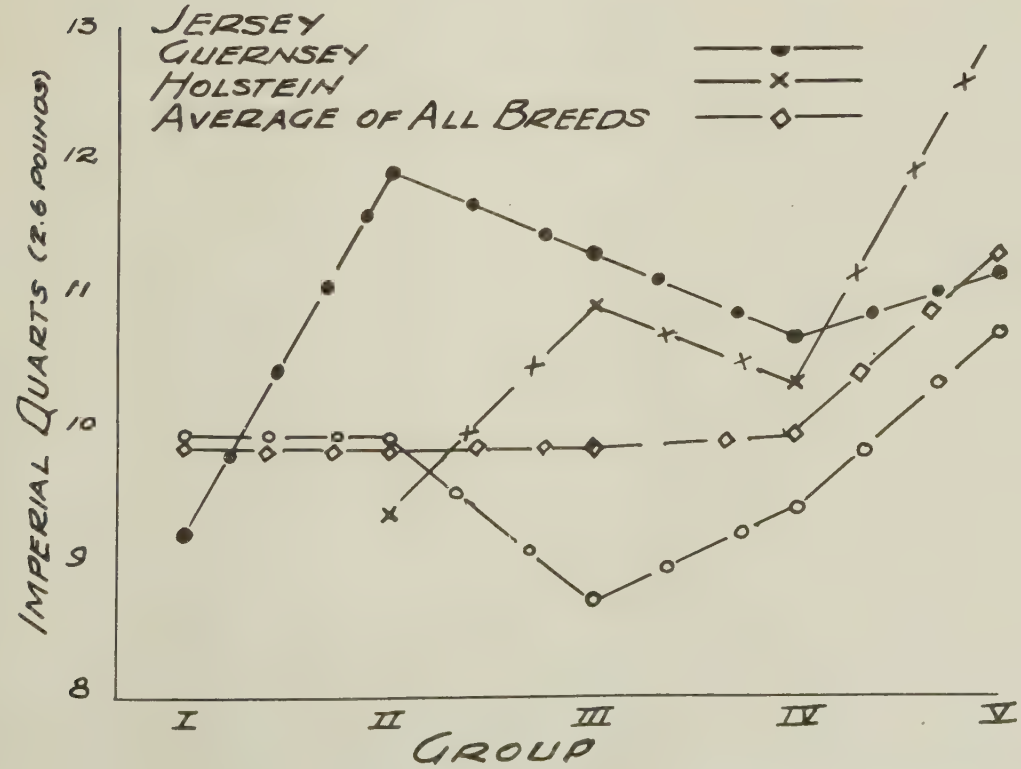

FIG. 12. MAXIMUM DAILY MILK PRODUCTION

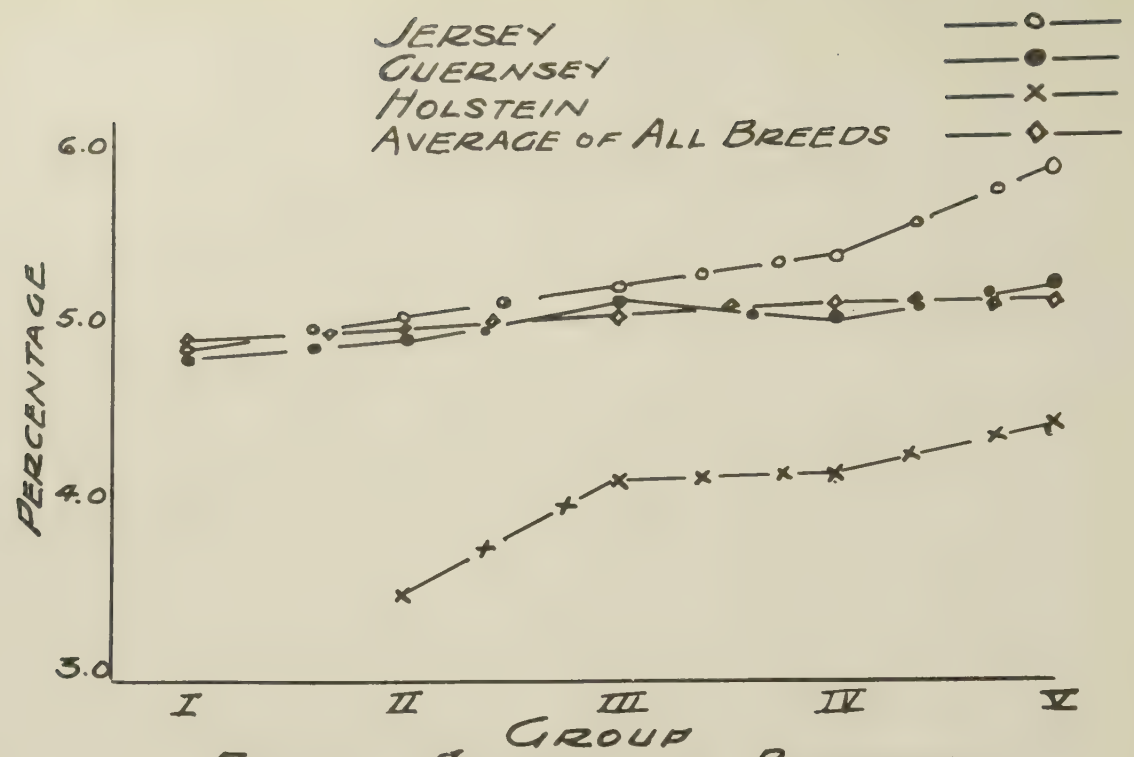

FIG. 13. PERCENTAGE BUTTERFAT

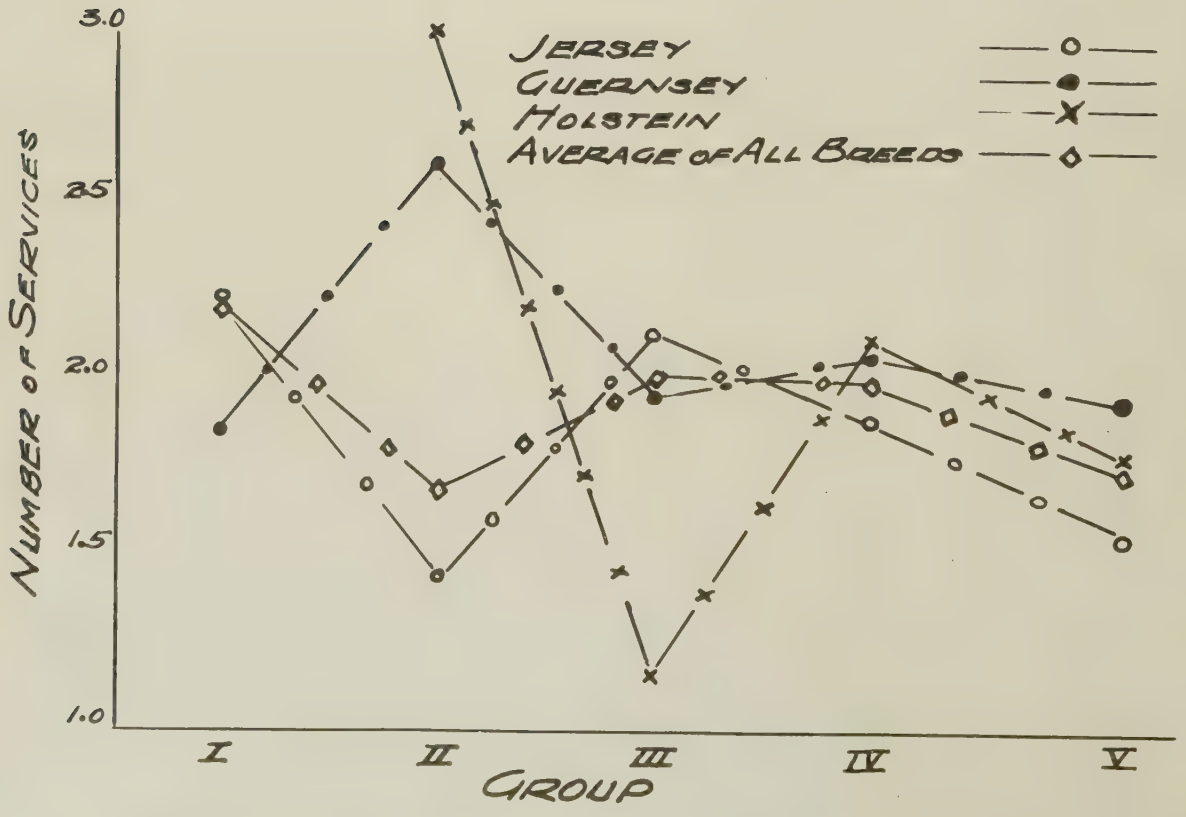

FIG. 14. NUMBER SERVICES PER CALF

Table 5. Average Maximum Daily Milk Production (in Imperial Quarts = 2.6 lbs)

Breed	Groups I	II	III	IV	V	Breed Av.	Standard Error
Jersey	9.96	9.90	8.70	9.40	10.70	9.67	± .14
Guernsey	9.23	11.93**	11.33	10.72	11.19	10.60	± .23
Holstein	—	9.35	10.90	10.30	13.06	11.54	± .37
Av. All Breeds	9.88	9.67	9.53	9.86	11.60		

Table 6. Analysis of Variance of Maximum Daily Milk Production.

Breed		Degrees of Freedom	Mean Square
Jersey	Within groups	521	9.68
	Between groups	4	34.75**
Guernsey	Within groups	152	8.57
	Between groups	4	33.08**
Holstein	Within groups	81	11.78
	Between groups	3	49.87**

Maximum Daily Milk Production

In Table 5 details of the maximum daily milk production are shown, with analysis of variance for this factor set out in Table 6. Maximum daily milk production for the various groups is shown graphically in Figure 1[a]

The maximum daily milk production for all breeds followed the same general trend as the total milk production per lactation, increasing with an increase in the amount of Zebu blood.

Differences between groups in each breed were found to be highly significant for maximum daily milk production.

Percentage of Butterfat in the Milk

The average percentage of butterfat in the milk of the various groups is shown in Table 7, while the analysis of variance for the butterfat test is set out in Table 8. Figure 13 shows graphically the butterfat percentage of the milk of the various groups.

Table 8. Analysis of Variance of Butterfat in the Milk

Breed		Degrees of Freedom	Mean Square
Jersey	Within groups	545	.44
	Between groups	4	10.92**
Guernsey	Within groups	321	.56
	Between groups	4	1.22
Holstein	Within groups	102	.33
	Between groups	3	1.13*

The general trend of the average butterfat test of all breeds was an increase in test with an increase in the amount of Zebu blood. In each of the three breeds the trend was smooth, rising steadily from the pure-bred group to the group having one-half Zebu blood.

The difference between groups was statistically significant in the Holstein and highly significant in the Jersey breed. Group differences in the Guernsey breed were not significant.

The greatest increase in test was in the Jersey breed which showed an increase of 1.0 percent between the pure-breds and half-breds. The increase in test of the Holstein was 0.95 percent while the increase in test of the Guernsey was the lowest of the three, being 0.42 percent.

The fact that the Jersey, which is normally the highest testing of the three breeds, showed the greatest increase, is contrary to results of work done on the inheritance of butterfat test. Data on this subject show that when animals of different northern breeds are crossed, the butterfat test of the cross-breds is usually intermediate between the two parents.

Table 7. Average Percentage of Butterfat in the Milk

Breed	Groups I	II	III	IV	V	Breed Av.	Standard Error
Jersey	4.89	5.08	5.22	5.40	5.89	5.18	± .03
Guernsey	4.85	4.99	5.18	5.09	5.27	5.11	± .04
Holstein	—	3.47	4.16	4.18	4.42	4.25	± .06
Av. All Breeds	4.89	4.99	5.08	5.13	5.18		

On the other hand, the smooth linear trend of the increase in butterfat test from the pure-bred to the half-bred indicates the possible existence of dominance among some of the genetic factors which determine butterfat percentage, the test showing a regular increase with an increase of Zebu blood. Pure-bred Zebus and Jerseys, and pure-bred Zebus and Holsteins may differ in more genetic factors for butterfat test than do pure-bred Zebus and pure-bred Guernseys. If there is dominance among genetic factors for butterfat test, and if the above conjecture concerning relative differences is true, then Zebu x Jersey and Zebu x Holstein cross-breds would show a greater increase in butterfat percentage over northern parents than would Zebu x Guernsey cross-breds.

The differences between groups in the case of the Jersey and Holstein breeds were found to be highly significant and significant respectively, with no significant difference in the Guernsey breed. This difference in reaction between groups may also account for the larger increase in the test in Jersey and Holstein breeds, and the small increase in the test of the Guernsey cross-breds.

Number of Services per Calf

Table 9 sets out the average number of services per calf for the various groups, while the analysis of variance for this factor is shown in Table 10. The number of services per calf is shown graphically in Figure 14.

Table 9. Average Number of Services per Calf

Breed	Groups I	II	III	IV	V	Breed Av.	Standard Error
Jersey	2.31	1.42	2.12	1.89	1.56	2.06	± .06
Guernsey	1.86	2.62	1.96	2.06	1.93	1.99	± .09
Holstein	—	3.00	1.16	2.10	1.76	1.86	± .19
Av. All Breeds	2.24	1.69	2.00	1.97	1.76		

Table 10. Analysis of Variance of Number of Services per Calf

Breed		Degrees of Freedom	Mean Square
Jersey	Within groups	437	1.73
	Between groups	4	10.00**
Guernsey	Within groups	199	1.69
	Between groups	4	1.08
Holstein	Within groups	52	2.03
	Between groups	3	.41

The general trend was a slight reduction in the number of services per calf as the amount of Zebu blood increased.

Differences between groups in the Jersey breed were found to be highly significant while no significance was found between groups in the Holstein and Guernsey breeds.

In explaining the effect of high atmospheric temperatures on fertility, Bonsma (1) found that high temperatures descreased the fertility of the bulls, the Afrikander breed being less affected than the northern breeds. This worker also found a seasonal fluctuation in the females, and attributes such fluctuation to the fluctuation in sexual activity rather than to a lower fertility in the bulls, the conception rate of the females being highest in the spring and fall.

It is probable that the findings mentioned may have affected the number of services per calf in the various groups in this study, but it is not possible to confirm this, since information as to the season of the year at which services were given, or the amount of Zebu blood of the bulls used was not available.

Lack of information makes it impossible to draw a definite conclusion as to the effects of Zebu blood on the number of services per calf until additional experimental evidence is available.

Table 11. Age at First Calving (in months)

Breed	Groups I	II	III	IV	V	Breed Av.	Standard Error
Jersey	34.7	42.9	37.6	39.0	39.2	37.58	± .52
Guernsey	38.6	46.6	43.8	43.1	42.7	42.94	± .77
Holstein	—	52.0	41.9	40.3	41.6	41.55	± 1.12
Av. All Breeds	35.25	44.22	40.24	40.62	41.80		

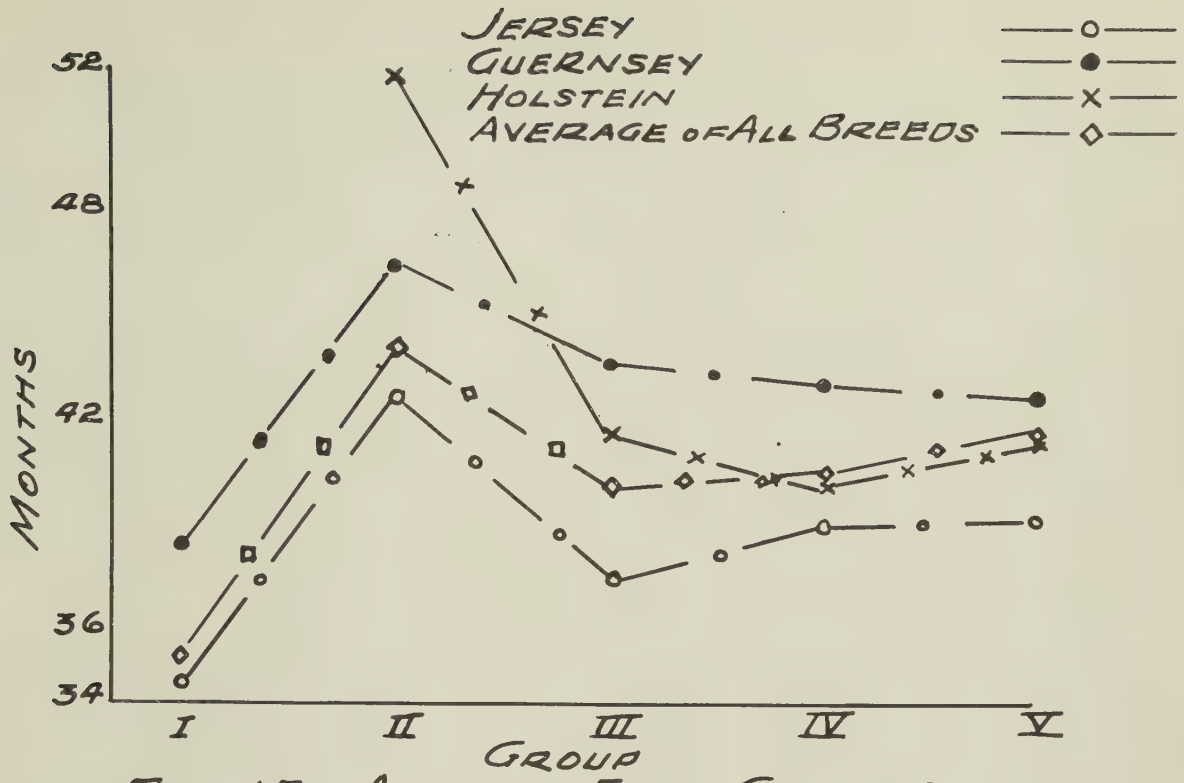

FIG. 15. AGE AT FIRST CALVING

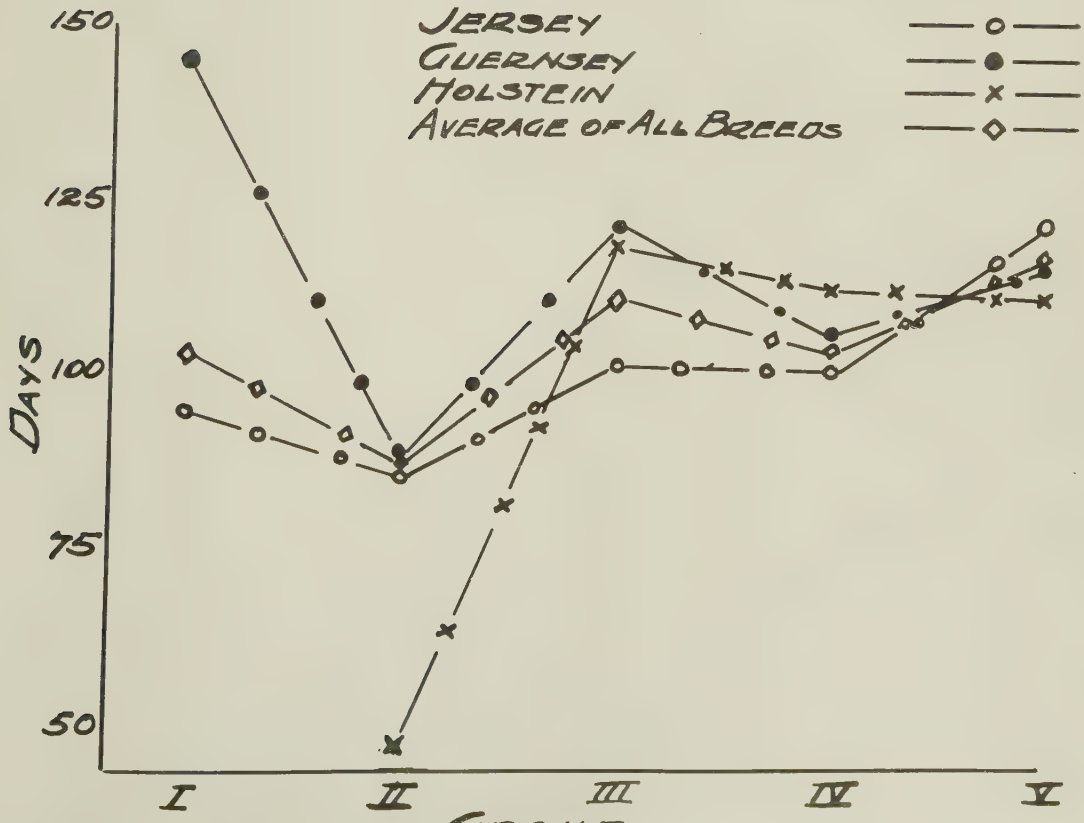

FIG. 16. DRY PERIOD

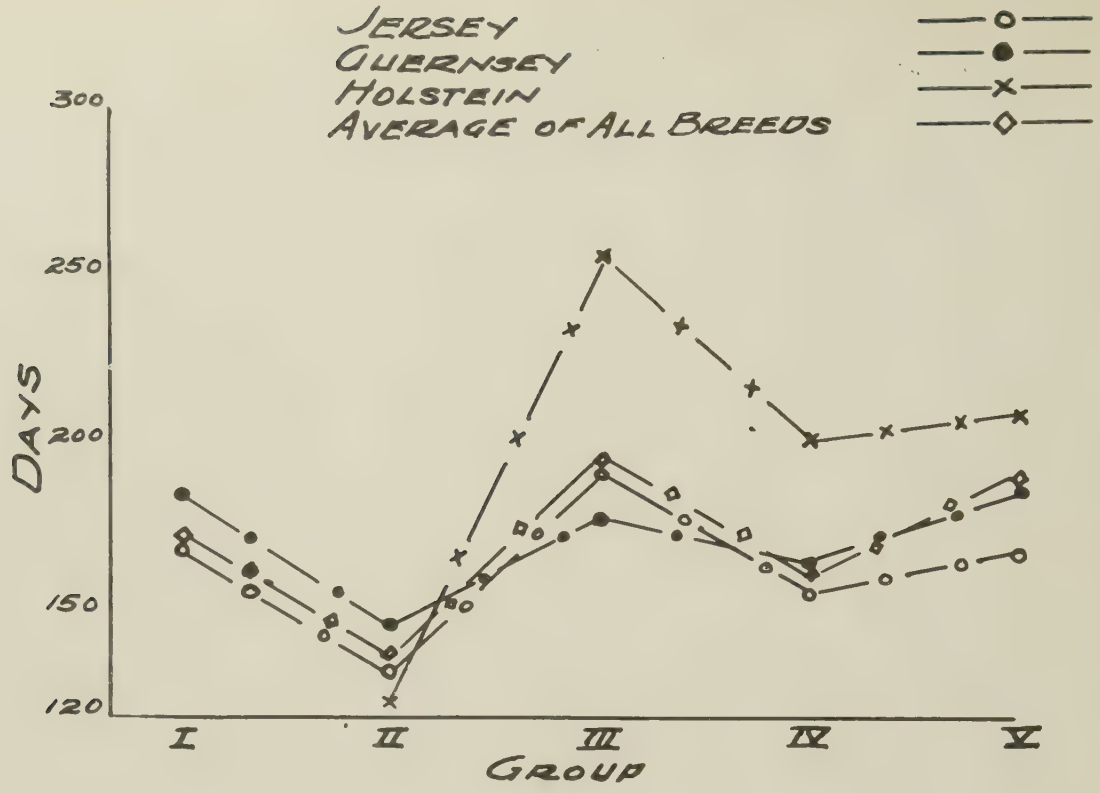

FIG. 17. SERVICE PER 100

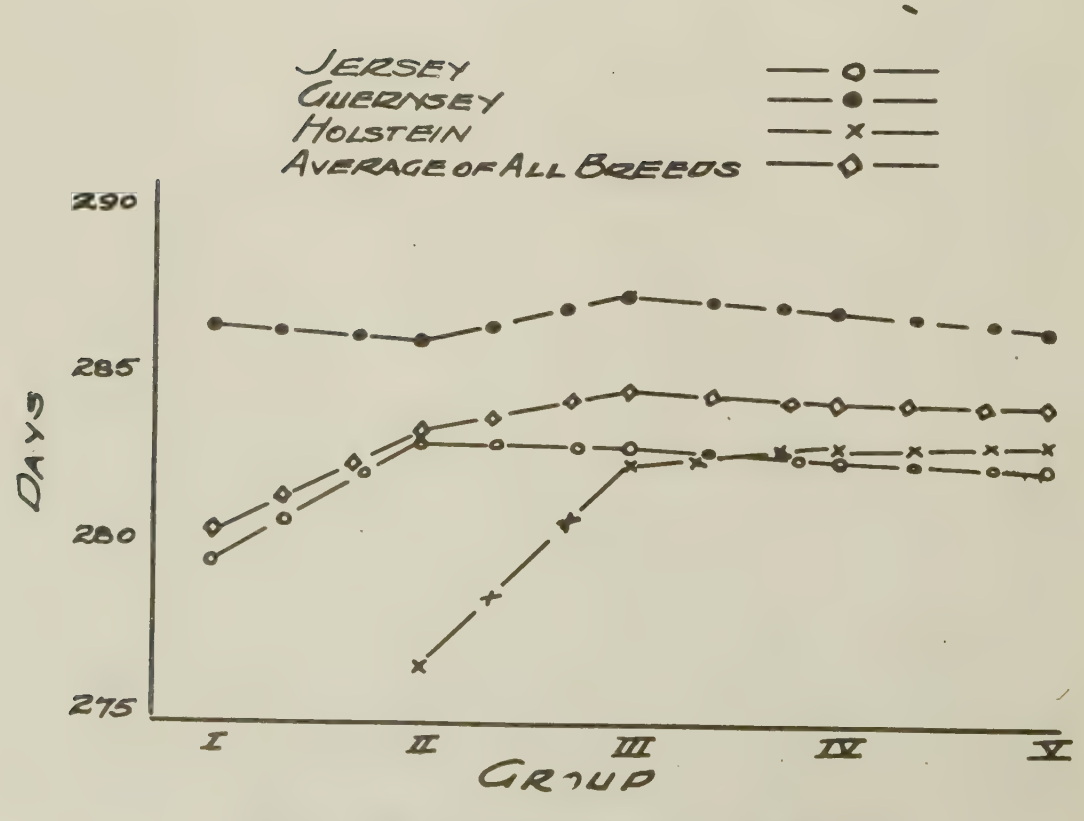

FIG. 18. GESTATION PERIOD.

Table 12. Analysis of Variance of Age at First Calving

Breed		Degrees of Freedom	Mean Square
Jersey	Within groups	194	58.5
	Between groups	4	319.8 **
Guernsey	Within groups	98	61.8
	Between groups	4	78.8
Holstein	Within groups	27	39.1
	Between groups	3	43.0

Age at First Calving

The age at which heifers calf for the first time is set out in Table 11, while the analysis of variance for age at first calving is shown in Table 12. The effects of Zebu blood on this factor are shown graphically in Figure 15.

The general trend was for the heifers to calve at a later age as the amount of Zebu blood increased. The age at first calving of the pure-bred Jerseys was 35 months, that of the pure-bred Guernseys 39 months. The calving age of the half-breds of these two breeds was 39 months, and 43 months respectively. The age at first calving of the half-bred Holsteins was 42 months.

While a highly significant difference between groups was found in the Jersey breed for age at first calving, no significant difference was found in the other two breeds.

From the uniformity of the trend of the three breeds for this factor, combined with the observations on the Hope herd, the conclusion can be drawn that animals with a high percentage of Zebu blood are slower maturing sexually than are animals of the northern breeds and, consequently, such animals calve for the first time at an older age than do those with no Zebu blood.

Length of Dry Period

The average length of dry period for the various breed groups is shown graphically in Figure 16, details being set out in Table 13.

Table 14. Analysis of Variance of Length of Dry Period

Breed		Degrees of Freedom	Mean Square
Jersey	Within groups	463	7,495
	Between groups	4	7,631
Guernsey	Within groups	259	12,538
	Between groups	4	14,955
Holstein	Within groups	82	13,697
	Between groups	3	3,148

Analysis of variance for this factor is shown in Table 14.

The general trend for all breeds was for the length of the dry period to increase as the amount of Zebu blood increased.

It was observed in the Hope herd that cows with a high percentage of Zebu blood were often difficult to get in calf during the time they were milking, and often could not be settled in calf until they were dried off.

Although the differences found between groups were not significant, the uniformity of the trend, combined with the observations made, tend to indicate that an increase in the length of the dry period results from an increase in the amount of Zebu blood .

Length of the Service Period

The length of the service period was calculated by subtracting 283 days or the length of the gestation period from the interval between calvings.

The service period is a means of measuring the breeding ability of the animal, since it is the length of the interval between calving and subsequent conception, while the breeding efficiency is the number of services required per conception.

The average length of the service period is shown graphically in Figure 17, while details and analysis of variance for this factor are set out in Tables 15 and 16.

Table 13. Length of Dry Period (in days)

Breed	Groups I	II	III	IV	V	Breed Av.	Standard Error
Jersey	96.5	87.3	103.6	102.4	123.3	100.4	± 4.0
Guernsey	146.6	85.9	122.8	107.5	117.1	116.7	± 6.9
Holstein	—	48.0	120.6	114.0	113.4	113.5	± 12.6
Av. All Breeds	104.7	85.7	113.7	105.7	117.9		

Table 15. Average Length of Service Period (in days)

Breed	Groups I	II	III	IV	V	Breed Av.	Standard Error
Jersey	169.9	131.8	192.2	155.9	169.0	165.8	± 5.5
Guernsey	186.1	147.6	179.7	164.5	187.1	173.8	± 8.3
Holstein	—	124.7	257.1	201.6	209.6	213.1	± 18.0
Av. All Breeds	172.5	135.2	194.0	164.2	187.8		

Table 16. Analysis of Variance of Length of Service Period

Breed		Degrees of Freedom	Mean Square
Jersey	Within groups	507	15,463
	Between groups	4	32,707
Guernsey	Within groups	266	18,761
	Between groups	4	8,990
Holstein	Within groups	84	28,615
	Between groups	3	20,275

The general trend for all breeds showed a slight increase in the length of service period with an increase in the amount of Zebu blood, and closely paralleled the trend of the dry period, there being a relationship between the two.

No significant difference was found between groups in any of the breeds.

Observations on the Hope herd indicate that animals with a large amount of Zebu blood do not come in heat as soon after calving as do animals of the northern breeds. While this is noticeable in a dairy herd, it is even more noticeable where cows are suckling their calves. As a result of the greater length of time after calving before such cows can be bred, the length of the calving interval increases with an accompanying increase in the length of the service period.

Gestation Period

A comparison of the length of the gestation period for the various groups is shown graphically in Figure 18, details and analysis of variance being set out in Tables 17 and 18.

Table 18. Analysis of Variance of Length of Gestation Period

Breed		Degrees of Freedom	Mean Square
Jersey	Within groups	346	37.1
	Between groups	4	216.2**
Guernsey	Within groups	164	31.6
	Between groups	4	6.0
Holstein	Within groups	40	25.2
	Between groups	3	26.3

The trend for all breeds showed a slight increase in the length of the gestation period as the amount of Zebu blood increased. Of the northern breeds, the Jersey was the only one which showed a significant difference between groups in length of gestation period.

The Guernsey breed had the longest average gestation period 286.9 days. Each group in this breed had a longer gestation period than did the corresponding groups in the other two breeds.

If the observed trend is real, the explanation is probably genetic. However, the differences observed may well have been due largely to individual non-genetic differences in response to environmental factors.

Sex Ratio

The number of calvings for all breeds was 1,155 of which 610 were males and 545 females.

The ratio between males and females for all calves dropped was computed for the various groups, expected numbers being based on: (1) a 1:1 ratio in each group, and (2) the actual ratio of males to females in the total of all calves dropped *viz.*, 1.119:1.0. The significance of the deviations were tested by chi-square.

Table 17. Average Length of Gestation Period (in days)

Breed	Groups I	II	III	IV	V	Breed Av.	Standard Error
Jersey	279.7	283.2	283.0	282.7	282.5	281.4	± .3
Guernsey	286.8	286.3	287.5	287.0	286.5	286.5	± .4
Holstein	—	276.5	282.7	282.9	283.0	282.6	± .8
Av. All Breeds	280.8	283.3	284.9	284.4	284.2		

The results are shown in Table 19

Table 19. Sex Ratio

	I	II	III	IV	V
Males	161	57	117	203	72
Females	144	37	104	186	74
Totals	305	94	221	389	146
Chi-square	0.95	4.26	0.76	0.74	0.03
Percentage males	52.8	60.6	52.9	52.2	49.3
Expected frequency of sexes based on totals :					
Males	161.02	49.6	116.7	205.4	77.1
Females	143.98	44.4	104.3	183.6	68.9
Chi-square	0.00	+2.33	0.02	0.06	0.72

When chi-square was applied to test the deviations from 1:1 in the sex frequencies, a significant difference was found only in Group II. In this case chi-square value barely exceeded the .05 level.

With the exception of Group V, the number of females was less than the number of males. The chi-square value of total calvings based on exact equality was not significant. No significance was found in expected frequencies of sexes based on the number of calves dropped.

Summary and Conclusions

1. *Growth Rate*

Animals with Zebu blood have a higher birth weight, and grow more rapidly than pure-breds of the northern breeds, the rate of growth increasing with an increase in the amount of Zebu blood.

The differences in growth rate appear to be more perceptible after the age of two years, the half-breds at maturity weighing on an average 179 pounds more per head than the pure-breds at the same age.

2. *Milk Production per Lactation*

Milk production during a lactation increased as the amount of Zebu blood increased, the greatest production being given by the half-breds.

Significant differences were found between groups in all breeds, in the case of the Jersey and Guernsey, such differences were highly significant.

Animals with one-half Zebu blood appear to be most suitable for milk production for conditions in Jamaica, but further work on this problem is necessary to determine whether the increase of the half-bred over the pure-bred is due to heterosis.

3. *Maximum Daily Production*

Maximum daily production of milk followed the same trend as total milk production per lactation.

The differences between groups for this factor were found to be highly significant for all the breeds tested.

4. *Butterfat Test of the Milk*

The butterfat test of the milk appeared to increase with the amount of Zebu blood. The Jersey breed showed the greatest increase in test, the milk of the half-breds of this breed testing 1.0 percent more than the pure-breds. The increase in the Guernsey breed between similar groups was 0.42 percent. The Holstein breed showed an increase of 0.95 percent between the groups with one-eighth Zebu blood and that with one-half Zebu blood.

The differences between groups were significant in the case of the Jersey and Holstein breeds, being highly significant in the case of the former. No significant difference was found in the Guernsey breed for butterfat test.

5. *Number of Service per Calf*

The number of services per calf was slightly reduced as the amount of Zebu blood increased.

The differences between groups were highly significant in the Jersey breed, no significant differences being found between groups in the other two breeds. Further investigation into this factor is necessary before a more definite statement can be made as to the effect of Zebu blood on the number of services per calf.

6. *Age at First Calving*

The age at which heifers calved for the first time tended to increase with the amount of Zebu blood.

The differences, however, while highly significant in the case of the Jersey breed, were found to be not significant for the Guernsey and Holstein breeds.

7. *Length of Dry Period*

The length of the dry period increased with an increase in the amount of Zebu blood.

The differences between groups were found not to be significant in any of the three breeds.

8. *Length of Service Period*

An increase in the amount of Zebu blood indicated an increase in the length of the service period.

The differences between groups were found not to be significant in any of the three breeds.

9. *Length of Gestation Period*

An increase in the amount of Zebu blood showed an increase in the length of the gestation period.

With the exception of the Jersey breed which was found to be highly significant, no significant differences between groups were found.

10. *Sex Ratio*

The ratio for all calvings was 52.8 percent males and 47.2 percent females.

The differences between numbers of the sexes were not significant statistically.

Acknowledgement

The writer takes this opportunity of expressing his thanks to Dr. Jay L. Lush, Professor in Animal Breeding, Iowa State College, for his valuable advice and counsel during the course of this investigation. To Dr. C. Y. Cannon, Professor in Dairy Husbandry, and to Mr. Robert R. Shrode, Research Senior Fellow, the writer also expresses his thanks for assistance given.

To Mr. H. H. Croucher, then Acting Director of Agriculture, Jamaica, the writer extends his thanks for making this study possible, by granting permission to use data from the herd records at the Government Stock Farm, Hope, Jamaica.

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THE PHOSPHATE STATUS OF SOME BRITISH GUIANA SUGAR-CANE SOILS AS ASSESSED BY A SIMPLE POT TEST

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INTRODUCTORY

In continuation of field and laboratory investigations of some sugar-cane soil profiles recently carried out by us in British Guiana at sites selected by Mr. R. R. Follett-Smith, the phosphate status of ten (10) samples of topsoil has been examined by means of a simple pot test. The samples were actually composite samples made up from profile samples representing the A-horizon, of average thickness 14 inches. Some were collected down to the 16, 17 or 20 inches depth.

The general features of the soils examined and their type relationships are shown by the laboratory data in Table I.

Discussion of laboratory data:

NOTE: The data in Table I are the actual analytical results obtained with the composite soil samples; they agree closely with the arithmetical means for the component profile samples.

Each of the soils is very highly *acid* (pH 5.3 or less). *Organic matter* and *nitrogen* contents are fairly high to medium on Trinidad standards, except the sample of true pegasse (No. IX; Wales (1)), which has an exceptionally high organic content. The Riverside Silt soils contain least organic matter and nitrogen. Carbon-nitrogen ratios are variable but tend generally to be low (less than about 11) in soils other than Pegassy Clay. This denotes either considerable surface erosion or organic wastage or profound biological breakdown of the organic component and a paucity of fresh plant residues (trash). None of the soils is salty except the first two Port Mourant soils (Nos. III and IV) which, however, contain only small and probably harmless amounts of salts (conductivity values not here recorded).

Available phosphate is relatively very low for all except two of the soils, of which one (No. I, Diamond (1)) is near the border-line of phosphate adequacy and the other (No. II Diamond (2)), which is very rich in available phosphate, had probably been recently manured with filter-press mud.

TABLE 1: LABORATORY DATA FOR THE SOILS EXAMINED

Soil-Sample	Sand content %	Index of Texture (I.T.)	Reaction Normal pH	Org. matter content %	Total nitrogen content %	C/N ratio	Avail. P_2O_5 p.p.m. †	Avail. K_2O p.p.m. †	Lime requirement t./ac. 6 ins.	Remarks
(A) FRONTLAND CLAY										
(III) Pt. Mourant (1)	9	42	5.1	3.8	.21	10.4	13	170	3.9	Flooded
(IV) Pt. Mourant (2)	7	46	5.0	3.3	.26	11.9	22	156	4.6	Not „
(V) Pt. Mourant (3)	7	40	5.0	3.5	.21	10.0	19	176	3.4	Flooded
(VI) Pt. Mourant (4)	6	42	5.2	3.2	.19	10.0	8	291	2.5	Not „
(B) PEGASSY CLAY										
(II) Diamond (2)	10	53	4.5	6.8	.21	18.5	(384)	216	13.6	Never Flooded
(VII) Blairmont (1)	8	45	4.9	5.5	.27	11.9	9	171	6.1	Not „
(IX) Wales (1)	-	(72)	4.3	85.3	1.11	44.6	12	127	15.0	Flooded
(C) RIVERSIDE SILT										
(I) Diamond (1)	7	50	4.7	3.1	.17	10.7	46	134	7.5	Flooded
(VIII) Blairmont (2)	25	22	5.3	3.0	.11	(16.5)*	28	110	1.5	Not „
(X) Wales (2)	5	42	4.5	3.1	.18	10.2	14	101	6.9	Flooded

† Values denoting possible inadequacy are **underlined**
* Contains considerable amounts of charcoal and cane-trash

Available potash is generally low, that is, less than the value provisionally accepted as the limit of adequacy for heavy sugar-cane soils (200 p.p.m.). The Riverside Silt soils show greatest potash deficiency.

Lime requirement: This was determined by the Hardy-Lewis electrometric titration method.* The values obtained are expressed in Table I as tons of calcium carbonate required theoretically to raise the reaction of one acre of surface soil, 6 inches deep, to pH 7.2. They range in magnitude from 1.5 to 15 tons per acre and tend to be highest for Pegassy Clay.

THE POT TEST

Procedure: Waxed cardboard containers (ice-cream cartons), holding 750 grams of 2 mm. sifted air-dry soil, were used. A hole was bored in the bottom of each pot and a layer of fine gravel was introduced for drainage. The soil was loosely packed on top and moistened from below by placing in a trough containing a shallow layer of water. Solutions of manures were next added in the pre-calculated appropriate quantities and the moist mixtures were allowed to stand for 10 days with occasional watering to allow the soil and the manures to interact and to come to equilibrium. Tomato seeds ("Bonny Best") were then sown. After germination, all but seven equally-spaced seedlings were removed. Those that subsequently died were replaced by seedlings grown in a box. The cultures were placed in a greenhouse and watered twice daily. †

Notes were made of the appearance of the tomato plants at different stages of growth. The experiment was discontinued when the plants were nine weeks old. Photographs were taken of the sets of cultures at this stage, and the crops were then reaped and the yields determined by drying and weighing. Roots were discarded.

Treatments: Each set of cultures included four manurial treatments, namely, (i) nitrogen alone (N), (ii) nitrogen and potash (NK), (iii) nitrogen, phosphate and potash (NPK), and (iv) treble-nitrogen, phosphate and potash (N_3PK). Unfortunately, the quantity of soil available was not sufficient for replicating the treatments nor for setting up a corresponding full series of limed soils. Instead, two series of cultures of limed soils only were prepared, having manurial treatments, (v) lime, nitrogen, phosphate and potash, ((L)NPK), and (vi) lime, treble-nitrogen, phosphate and potash ((L)N_3PK). The lime used was a mixture of calcium sulphate and calcium carbonate (see below).

The unit amounts of artificial manures employed were proportionate to those used in the standard Mitscherlich pot-test, namely, 12½ cwt. per acre of ammonium sulphate, 16 cwt. per acre of superhosphate and 7½ cwt. per acre of potassium sulphate. These unit quantities are much larger than the amounts that would customarily be applied in practical sugar-cane growing, particularly for phosphate, but they are deliberately chosen so as to allow for possible immobilisation of part of their nutrient components through absorption and fixation by the soil.

In this particular pot-test with the British Guiana soils, ammonium nitrate was actually used instead of ammonium sulphate, because if, on the one hand, natural nitrification is sluggish, there may still be a sufficient supply of nitrate to meet the immediate needs of the growing plants, and on the other hand, if the plant exhibits preferential absorption of ammonium-ion, a sufficient supply of this nutrient may also be available for utilisation. Instead of commercial superphosphate, pure mono-calcium hydrogen phosphate was used, since this completely dissolves in water, whereas superphosphate is only partly soluble. It also contains no calcium sulphate.

Liming was carried out in the limed series of cultures as follows. Into each of the soils to be limed was intimately mixed 3 grams of dry powdered gypsum (calcium sulphate hydrate). Then the full theoretical lime requirement amount of precipitated calcium carbonate was suspended in a small quantity of water and carbonic oxide gas was bubbled in until most of it had dissolved as calcium bicarbonate. This solution was then slowly mixed with the gypsum-treated soil kept constantly stirred. The crumbly moist mixture was next packed into the cartons, wetted from below, allowed to stand for 10 days and then sown with tomato seeds. The object of the gypsum and lime treatment was to ensure a high degree of calcium saturation as well as partial neutralisation of soil acids. How far these objects had been achieved was ascertained by sampling the soil in the cartons with a cork borer at the end of the experiment and determining the pH value and observing the colouration imparted to Comber's reagent (ammonium thiocyanate in alcoholic solution). The results obtained are given in Table II.

Effect of liming on soil reaction: The data in Table II indicate that the change in pH value caused by liming in the two lime treatments, namely, (v) (L)NPK and (vi) (L)N_3PK, was relatively small; the final normal reaction in no

* *Journ. Agric. Sci.*, 1929, XIX, p. 17.

† The greenhouse operations were carried out by C. Baboolal, Technical Assistant.

TABLE II : EFFECT OF THE LIMING ON SOIL REACTION

Soil-Sample	Reaction of initial soil		Reaction after liming				Comber colour and mark			
	Norm.	Exch.	(v) (L) NPK		(vi) (L) N_3PK		(v) (L) NPK		(vi) (L) N_3PK	
	pH	pH	Norm. pH	Exch. pH	Normal pH	Exch. pH				
(A) FRONTLAND CLAY										
(III) Pt. Mourant (1)	5.1	4.4	5.9	5.5	5.1	4.6	Pink	(2)	Red	(7)
(IV) Pt. Mourant (2)	5.0	4.2	5.4	5.0	5.3	4.8	Dk. pink	(4)	Lt. red	(5)
(V) Pt. Mourant (3)	5.0	4.2	5.3	4.9	4.9	4.5	Lt. red	(5)	Red	(7)
(VI) Pt. Mourant (4)	5.2	4.3	5.4	4.9	4.9	4.4	Dk. pink	(4)	Dk. red	(8)
(B) PEGASSY CLAY										
(II) Diamond (2)	4.5	3.8	5.9	5.6	6.0	5.4	Dk. pink	(4)	Dk. red	(8)
(VII) Blairmont (1)	4.9	3.9	5.4	5.2	5.5	5.1	Pink	(3)	Dk. pink	(4)
(XI) Wales (1)	4.3	3.8	5.4	4.8	5.5	4.9	-			
(C) RIVERSIDE SILT										
(I) Diamond (1)	4.7	3.7	5.8	5.4	5.5	4.8	P. pink	(1)	Lt. red	(6)
(VIII) Blairmont (2)	5.3	4.5	6.1	5.9	5.1	4.8	C'less	(0)	Lt. red	(5)
(X) Wales (2)	4.5	3.8	5.5	5.0	5.0	4.4	Pink	(2)	Dk. red	(8)

instance was over pH 6.1. In some cases indeed the pH value had scarcely been changed at all by the liming. The correct explanation of this is probably that each of the limed cultures contained a large quantity of ammonium nitrate which presumably, on nitrification of the ammonium constituent, generated a relatively large amount of nitric acid. Each culture also contained a considerable quantity of acid calcium phosphate. Furthermore, the lime added was mainly calcium bicarbonate which itself may have been slightly acid in reaction (pH 6.0).

On the other hand, it would be expected that the calcium status at least would have been greatly raised by the gypsum-lime treatment. The Comber colours are mostly pink in the first treatment which supports this expectation, though red in the second treatment that contained a triple dosage of ammonium salt. Evidently the lime added was not sufficient in quantity nor in degree of alkalinity to neutralise all the acidity developed in the soil system, nor to effect complete lime saturation. Nevertheless, the benefits bestowed by the treatment, as expressed in terms of plant growth (see below), were considerable.

Observations during growth : The characteristic symptoms of phosphate shortage developed within two or three weeks after germination. They consisted of a deep purple colouration of the hypocotyl and the under surfaces of the leaves and a darkening of the green colour of the upper leaf-surfaces. The phosphate-starved plants also showed stunted growth and wither tip. Certain of the cultures exhibited *chlorosis* to varying degrees. The most chlorotic plants were the NPK cultures, both unlimed and limed. The N_3PK cultures were less generally affected by chlorosis. This suggests that, when abundant phosphate and potash are present, the amount of available nitrogen supplied by the single-nitrogen treatment may be insufficient to meet the full needs of the plant and nitrogen starvation, manifest by a yellowing of the leaves, ensues. Certain other peculiar symptoms appeared in some of the cultures; these are mentioned in the notes on the behaviour of the different soil-types which follow; they are also indicated on the sheets of photographs appended.

Many of the limed cultures containing added phosphate showed a distinct purple colouration of the stems of the tomato plants. This may be an indication of phosphate shortage induced perhaps by phosphate fixation by excess of lime or fixation by active components of the soil itself. The appearance was generally most marked in the treble-nitrogen cultures ((L) NPK), especially of Riverside Silt samples, and in both single and treble nitrogen cultures of Pegassy Clay. It was not further investigated.

Yield results : The quantitative results are brought together in Table III, in which the oven-dry weight for each crop of seven plants yielded by the different cultures is recorded in centigrams. In the few cases where the number of plants was greater or less than seven, the weights were corrected to that for seven plants. Photographs of the actual cultures are appended. It may be noted that, in many of the cultures, the individual plants attained different heights and bulk. Hence too much reliance cannot be placed on the absolute value of the yield data. The pot tests are meant mainly to indicate general trends, being merely preliminary in kind.

TABLE III: RESULTS OF POT TEST
(Tomato plants, 9 weeks old)

Values are centigrams of dry matter per culture of 7 plants						
	UNLIMED SERIES				LIMED SERIES	
	Nitrogen N	Nitrogen, potash NK	Nitrogen phosphate, potash NPK	Triple nitrogen phosphate, potash N_3PK	Nitrogen, phosphate, potash (L)NPK	Triple nitrogen, phosphate, potash (L)N_3PK
	i	ii	iii	iv	v	vi
(A) FRONTLAND CLAY						
(III) Pt. Mourant (1)	112	110	310	210	520	622
(IV) Pt. Mourant (2)	5	22	17*	255	550	650
(V) Pt. Mourant (3)	90	100	295	300	550	720
(VI) Pt. Mourant (4)	20	10	305	280	480	670
(B) PEGASSY CLAY						
(II) Diamond (2)	14	5	32†	12†	415†	475†
(VII) Blairmont (1)	10	20	280	235	410	455
(IX) Wales (1)	—	—	—	—	502‡	70‡
(C) RIVERSIDE SILT						
(I) Diamond (1)	17	5	185	20	370	445
(VIII) Blairmont (2)	20	19	170	355	66	315
(X) Wales (2)	10	5	125	26	530	758

* Low yield due to severe chlorosis and stunting.

† Leaves scorched, especially limed plants.

‡ The position of these cultures was inadvertently reversed in photographing.

Notes on results for different soil-types:

The following broad generalisations are based on the semi-quantitative and qualitative results obtained in the pot test.

(A) FRONTLAND CLAYS

A superior phosphate status for the *flooded* soils (Nos. III and V, Port Mourant (1) and (3), as contrasted with the *unflooded* soils (Nos. IV and VI, Port Mourant (2) and (4)), which was not brought out by the Truog test, is strongly indicated by the yield data of the tomato test plants and is clearly shown in the photographs. Potash (NK) exerted only slight positive effect. Phosphate (NPK, N_3PK) increased the yields very greatly, except for No. IV, Port Mourant (2), which developed severe chlorosis in the NPK culture, possibly because of an insufficiency of available nitrogen. Chlorosis was not shown by the N_3PK culture of this sample, a fact which supports the explanation suggested. It should be noted that slight chlorosis was also shown by the NPK cultures of the other three Frontland Clay (Port Mourant) soils, although slightly more pronounced in the unflooded than the flooded soils. In no case was an N_3PK culture chlorotic.

The effect of liming was very marked and the treatment was apparently highly beneficial, especially in the (L)N_3PK cultures which contained most added nitrogen. Slight chlorosis was shown by two of the (L)NPK cultures. All the (L)N_3PK cultures developed marked purple colouration of the stems, but it is not certain that this denotes phosphate shortage in the presence of an excess of available nitrogen.

(B) PEGASSY CLAY

This gave peculiar results in the pot-test. The pure pegasse (No. IX, Wales (1)) was examined only in limed cultures, there not being sufficient soil for tests without lime. This soil responded to phosphate and lime, though less when extra nitrogen was supplied. The limed cultures still showed purple colouration even though phosphate had been added. One of the pegassy clays (No. II, Diamond (2)) gave a very high Truog value for available phosphate (384 p.p.m.), yet the pot test showed great phosphate shortage (N,NK). The limed cultures of this soil gave fair yields but they both showed a peculiar leaf-scorch, as well as slight chlorosis, accompanied by leaf-curl. The unlimed cultures also showed slight scorch and distinct chlorosis. The causes of these affections were not determined.

The Blairmont pegassy clay (No. VII) showed marked phosphate shortage. It responded well to phosphate manure and lime, and extra nitrogen gave additional yield res-

(A) FRONTLAND CLAY

UNLIMED SERIES

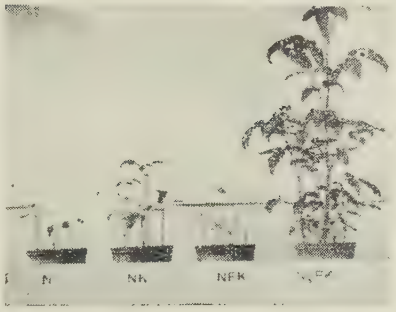
LIMED SERIES

Very slight chlorosis in NPK

No chlorosis. Purple stems

(III) PORT MOURANT (1) — Flooded

Severe chlorosis in NPK, slight in N.



No chlorosis. Purple stems in $(L)N_3PK$

(IV) PORT MOURANT (2) — Not Flooded

Normal plants

Slight chlorosis in (L)NPK. Purplish stems in $(L)N_3PK$

(V) PORT MOURANT (3) — Flooded

Slight chlorosis in NPK. Leaf mottle in N_3PK

Slight chlorosis in (L)NPK. Purplish stems in $(L)N_3PK$

(VI) PORT MOURANT (4) — Not Flooded

(B) PEGASSY CLAY

UNLIMED SERIES

LIMED SERIES

Stunted, chlorotic plants; slightly scorched NPK, N_3PK

Scorched, chlorotic plants. Purple stems.

(II) DIAMOND (2)

Normal plants

No chlorosis. Purplish stems

(VII) BLAIRMONT (1)

No Soil

Deep purple stems

(IX) WALES (1) — (Three plants)

(Pure Pegasse) Note : The treatments should be reversed.

(C) RIVERSIDE SILT

LIMED SERIES

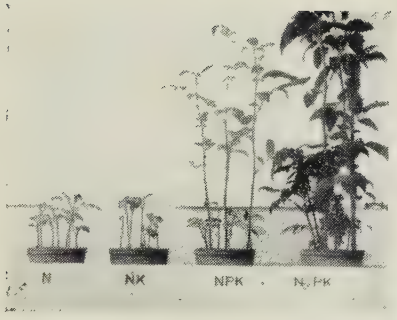
UNLIMED SERIES

All slightly chlorotic. Stunted N_3PK

Slight chlorosis in (L)NPK. Purple stems

(I) DIAMOND (1)

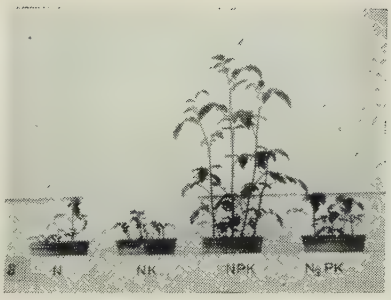
Severe chlorosis in NPK



Severe chlorosis in (L)NPK

(VIII) BLAIRMONT (2)

Stunted N_3PK



Slight chlorosis in (L)NPK. Purplish stems

(X) WALES (2)

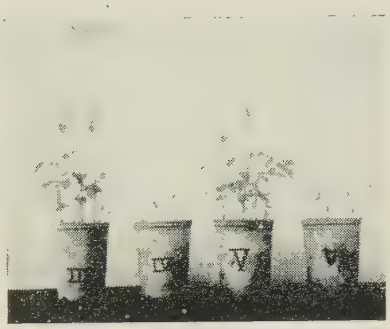
(D) COMPARISONS

(A) FRONTLAND CLAY : Port Mourant samples

UNLIMED SERIES

LIMED SERIES

Note difference between flooded and unflooded soils



CONTROL : N only

FULL TREATMENT
$(L)N_3PK$

(B) PEGASSY CLAY

UNLIMED

Note different effects of NPK

N : NPK

(C) RIVERSIDE SILT

UNLIMED

Note very poor growth with N only

CONTROL : N only

ponse. There were no signs of chlorosis nor leaf-scorch in any of the cultures of this sample.

(C) RIVERSIDE SILT

The cultures all showed marked phosphate shortage (N,NK), even the first set (No. (I), Diamond (1)) in which the soil apparently contained somewhat more than an adequate amount of available phosphate according to the Truog test (namely, 46 p.p.m.). The first and the third sets (Nos. I and X; Diamond (1) and Wales (2)) were peculiar and outstanding in that they both showed markedly depressed yields in the additional nitrogen cultures (N_3PK). This was evidently overcome by liming. No explanation of this peculiarity can be advanced at this stage.

The second set of cultures (No. VIII (Blairmont (2)) showed severe chlorosis in the NPK cultures, both with and without lime, although it was not discernible in the extra nitrogen cultures (N_3PK), even when limed. These facts suggest that the chlorosis is due to nitrogen shortage incident on the raised phosphate and potash status brought about by manuring. The soil contained an initial relatively-low total nitrogen content which may partly account for a deficiency in available nitrogen. Slight chlorosis was also showed by the (L) NPK cultures of the other two soils (Nos. I and X, Diamond (1) and Wales (2)). These, however, also showed slight purple colouration of the stems of the tomato plants in both of the limed cultures, which may or may not be indicative of phosphate shortage.

CONCLUSIONS

It should be understood that these simple pot test experiments are merely preliminary and meant to indicate (which they do very strikingly) the peculiar nutrient relationships of the sugar-cane soils of British Guiana. They clearly demonstrate that markedly beneficial responses to phosphate manure and to lime may be expected, provided these are applied in suitable kind and quantity (which may need to be relatively very great), and properly incorporated into the soil. Furthermore, they suggest that the full utilisation of added nitrogenous manure may be dependent on the previous attainment of an appropriate phosphate, calcium and reaction status.

It is recommended that simple pot tests along the lines of those herein described be inaugurated in British Guiana on a wide and comprehensive scale, and that they should include, not only representative samples of the chief soil-types, but also samples of soil before and after flood-fallowing, as well as samples of soil taken from the several plots of field manurial experiments now in being, in order to determine whether or not the manures have reacted with the soil to which they have been applied. They might also be employed to compare different kinds of phosphatic and nitrogenous manures, and different forms and grain-sizes of agricultural lime, commercial calcium compounds and other amendments. Besides Tomato as test plant, other indicator plants might be tried, for example, Sudan Grass, Hill Rice, Sunflower and Radish.

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REVIEW

COLONIAL LAW, by C. K. Meek, *pp. 58. Published by Geoffrey Cumberlege, Oxford University Press, London, 1948. Price: 4s. 6d.*

Not a textbook but a valuable short bibliography of colonial law with special reference to native African systems of law and land tenure, produced with the financial help of Nuffield College; it is the fifth in a series of bibliographies published under the editorship of Miss Margery Penham. Written primarily for the guidance of members of the Colonial Service the bibliography is likely to be of greater assistance to the Administrator than to the Agriculturist who would be disappointed if he expected direct guidance in the drafting of legislation for soil conservation, land settlement, or produce movement control. All members of the Colonial Service should be made aware of the existence of this useful little book and a copy should be kept available in official libraries at central and provincial headquarters.

C.W.L.

NOTES ON A VISIT TO COLOMBIA

Some Observations on the Diseases of Coconuts and Bananas in the Province of Magdalena

BY

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Introduction

At the request of some of the planters in the Magdalena Banana Zone, the writer was authorised by the Government of Jamaica to pay an advisory visit to Colombia in February, 1948.

The area concerned lies in the alluvial coastal plane between the Sierra Nevada de Santa Marta and the mouth of the Magdalena River, but Santa Marta, the capital town of the province, is the shipping port for the agricultural produce of the district. The soils of the " zone ", derived from the Sierra Nevada, consist of alluvial material varying from gravels and coarse sands to fine clays and silts of good physical texture, as already noted by Wardlaw (1929). The area, although subject to a marked dry season in the winter months (December to March), is well watered by the streams from the Sierra, and in consequence plentifully irrigated, and the ideal conditions prevailing in the greater part of it are reflected in magnificent banana crops, rapidly growing coconuts, and fruit trees, such as mango and avocado pear, attaining a size quite remarkable to a visitor from the West Indian islands.

Bananas had for many years been the chief, in fact almost the only, crop of the " zone ", but with the cessation of shipping facilities during the war, and also the increasing ravages of Banana Leaf Spot Disease (*Cercospora musae*), farmers had to look to the possibilities of other crops, and some started interplanting with coconuts. Cacao also is found with the bananas, and in one instance both coconuts and cashew had been included. At the southern end of the " zone ", near Aracataca, large areas of abandoned banana lands are now planted to rice.

The appearance of certain diseases on the newly-planted coconuts was the primary cause of the writer's visit, farmers in Colombia having had little previous experience with this crop. Opportunity offered at the same time to make observations on bananas and in particular of Leaf Spot.

Coconuts

The first feature that strikes the visitor on seeing the young coconut palms is their very rapid growth and early and heavy bearing. Plate I, showing a palm about five years old, gives a good indication of this, and of the unusual elongation of the crown, even for a young palm, attributable in part to the surrounding bananas and consequent accentuation of upward growth. As a result of interplanting and the consequent humid conditions prevailing, spotting by *Pestalotia palmarum* Cooke is quite commonplace on the lower leaves, though of no serious consequence, and the soft nature of the tissues encourages the presence of scale insects, sometimes seen on the surface of the maturing nuts, as well as on the older leaves, but not seriously deterrent to growth.

A disease which has given more cause for alarm is the occurrence of extensive growth cracks on the surface of the nuts. On inspection it was found that a browning and death of the skin of the young nuts originates under the calyx, where all longitudinal growth of the nut takes place (Leach, 1946b). Microscopic examination of the affected surface tissues showed gum formation in the cells immediately below the epidermis, but there was no organism present, and the symptoms were quite superficial. As a result however of the death of the surface tissues, when subsequent growth in girth of the nut takes place, splitting ensues, resulting in shallow fissures on the surface of the nut (Plate II). In some cases the cracking was accompanied by the oozing of gum. In extreme instances the whole surface of the nut was affected, and its normal expansion severely checked, in other cases restriction in girth of the middle part of the nut resulted. More often, however, only portions of the surface were malformed, or the symptoms only appeared late in the maturation of the nut, being confined to the basal area, and though unsightly, did not seriously affect the total size of the nut nor, therefore, the amount of copra contained within, the most important factor.

The writer has been unable to discover any references by other observers to a similar condition, although a short account by Dwyer (1937) of a Ring Disease of Immature Nuts in New Guinea may refer to the same thing. Exactly the same condition has however been observed by him in British Guiana (Martyn, 1930), though not considered of any consequence by

PLATE I. Young Coconut Palm, showing heavy bearing and unusual elongation of the crown.

PLATE II. Coconuts affected by surface growth cracks

planters there, and more recently, as a result of particular observation, portions of the surface of mature coconuts in Jamaica have been noticed as similarly affected. It is probable therefore that something of the same sort could be found in other coconut-growing countries, but is generally of such small significance as to attract no attention.

It appears that the cracking is entirely physical in origin, no organism being involved, and as the disease has been noted on alluvial soils in both Guiana and Colombia, with a water table that is generally high, and subject to fairly rapid fluctuation, it seems probable that the water relationships of the plant are the chief factor concerned in the occurrences of this abnormality of the nut surface, as they are in other forms of growth cracking. The fact that in Colombia the disfigurement and malformation of nuts are most apparent in young and rapidly-growing palms, subject to continual irrigation, or in localities where the water table may constantly vary, lends support to this hypothesis. In mature coconut palms seen in villages between Santa Marta and the banana zone, where regular irrigation is not practised, the disease was either absent or only present to a negligible extent, and it seems likely that as the newly-planted palms mature, and their growth rate slows down, the abnormality described will become less evident. There was some evidence that certain types of nut are more liable to this condition than others.

In those cases where the palms are interplanted with bananas regular irrigation is required throughout the dry season, and carried out at intervals of three to four weeks. This, though desirable for the bananas, is far more frequent than would be needed by the coconuts alone, and in one plantation heavy falls of very young nuts were noted, and were attributed to the frequent application of water.

In some instances, however, on clay soils, far from repeated irrigation, drainage is more necessary. In one plantation on clay, where coconuts only were grown, apparent " Drought Wilt " symptoms were to be observed, namely, the collapse of the outer leaves by the breaking or buckling of their petioles, together with the drying out of the more upright leaves in the centre of the crown. On investigation it was found that the water table was at about eighteen inches, and the root system almost entirely rotted away, so that despite constant irrigation, little or no water could be taken up and wilting resulted in the dry season. Other palms in this same field showed extensive stem bleeding, and many cases of malformation of the crowns, of the nature of " Bitten Leaf " (Martyn, 1945). The heart of the sickly palms had been subject to insect attack, probably by a species of " Rhinoceros Beetle ", sometimes resulting in the death of the growing point and, therefore, of the palm, while in other cases the growing point had not been destroyed and partial recovery had taken place, a crown of malformed and reduced leaves being produced.

In certain other plantations, the attack of a species of *Rhynchophorus* beetle caused the death of young palms. The collapse of the outer leaves was the first symptom, and on cutting open the soft, thick boles of the affected palms, the large grubs of the beetle were found within, causing destruction of so much of the inner stem tissue that wilting and death ensued.

It may be noted that no evidence was obtained, by hearsay or otherwise, of the occurrence of the Unknown Disease of Coconuts (Leach, 1946b) in Colombia, but enquiry from individuals conversant with the Caribbean coast of Central America indicated the occurrence of what is almost certainly the same disease on this coast, notably in Honduras and Panama.

Bananas

In the banana zone the cultivation and marketing of bananas are getting under way again after the setback due to the war. From the pathologist's standpoint the most unique feature is the continued absence of Panama Disease (*Fusarium cubense*) in this part of Colombia. Having regard to its geographical position, and the constant contacts with the banana world of Central America and the Caribbean, throughout the whole of the remainder of which the disease is present, as well as in adjoining parts of South America, it is very difficult to believe that the casual organism has never been introduced, though Wardlaw (1935) stated that Reinking and Manns did not find *F. cubense* in the soils of the " zone ". Also the writer was informed that in large samples of soil from the " zone ", shipped by the United Fruit Company to Central America for experimental purposes, bananas grown therein proved easily susceptible to introduced infection. It is conceivable that the position of the " zone ", sheltered in the lee of the Sierra Nevada de Santa Marta from the prevailing Trade Winds (though liable to serious wind storms of local origin), may afford some protection from possible air-borne introduction, but it is still difficult to explain the continued absence of the disease, especially as Banana Leaf Spot has been present for about ten years. The latter is however more rapidly spread than Panama Disease by banana trash, which under the conditions of the banana trade is liable to carry the Leaf Spot disease wherever banana boats go.

Banana Leaf Spot, or Sigatoka Disease as it is known in Colombia, is now seriously threaten-

ing many of the older plantations. It is probable that if the war had not intervened the threat would have developed earlier, but it is also apparent that the disease, after its initial occurrence in the area, did not make such rapid and widespread an advance throughout the cultivations as in other territories in this part of the world, and there are still plantations in the zone where no spraying has been done hitherto and where the disease is as yet of no serious account. This very lack of spraying has however resulted in the present heavily infected state of some of the plantations, and their marked contrast to those nearby, especially of the United Fruit Company, where spraying has been a regular practice. The absence of Panama Disease and the consequent potential permanency of banana cultivation in any given area, together with the level nature of the land and the continuity of the cultivations, make it worthwhile to devote considerable capital expenditure to the erection of pipe lines, and thus enable large areas (e.g. 600 acres) to be covered by spray pumped from a stationary plant housed on a central site.

The writer's visit was in the dry season, when the disease is least in evidence, despite which, however, one or two unsprayed plantations were seen which were heavily infected, and on one farm the maturing fruit was falling owing to breaking of the stem before harvesting — a well known symptom of the disease at its worst. All the infection observed, however, was more marked on one side of the leaf, *i.e.*, conidial, and despite a special search, only one or two leaves were seen throughout the visit which showed even apparent symptoms of " Tip Spotting ", due to ascospore infection (Leach, 1946a). It seems possible, therefore, that the perfect stage of the fungus is either absent, or of only occasional occurrence in the " zone ". Such a condition is compatible with the fact, discovered by Leach, that in Jamaica the intensity of perithecial formation is closely correlated with soil conditions, and tends to be least on some of the best banana soils. It would also account for the less serious effect of the disease hitherto in the Magdalena province as a whole than in some other parts of the Caribbean area.

It was difficult to obtain accurate information as to the extent of seasonal dew formation in different parts of the " zone ", but in some districts the comparatively small amount of dew appears to be an important factor in checking the disease. On the other hand, absence of " wintering ", such as occurs in Jamaica at high altitudes, and the fact that there is continual fairly rapid growth throughout the year, would explain the need for more frequent spraying cycles than are necessary in the latter island.

It may be noted that certain farmers in the " zone " are exploring the possibility of control of the disease by dusting from a helicopter, and although dusting in the past elsewhere has not proved successful in checking Leaf Spot, it will be of interest to see whether the new method of application may succeed in this particular area, where conidial infection predominates.

The other type of Leaf Spot, known generally as " Cordana ", although the relative part played in its production by *Cordana musae*, *Helminthosporium torulosum*, and possibly other weak parasites varies in different banana-growing areas, was commonly present, and on one or two farms was more conspicuous than the Sigatoka. In fields where the salt content of the soil was high, large scorched areas in the older leaves, roughly rectangular, were attributed to excessive salinity, and in some parts of the " zone " the salt content is too high for banana cultivation. Wardlaw (1935) also refers to this, and to other physiological diseases in Colombia due to lack of drainage.

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STUDIES IN CROP PHYSIOLOGY

Effect of Time of Application of Nitrogen Upon Growth Yield and Juice Quality of Cane

BY

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Introduction

The investigations conducted at this Research Station on the physiology and chemistry of sugar-cane (1) have indicated the outstanding effect of nitrogen in augmenting growth, vegetative vigour and yield of this crop. Data pertaining to (i) the comparative effects of this and other mineral ingredients (3, 5), (ii) the photosynthetic responses of mineral ingredients when applied in varying ratios and combinations (2), (iii) the physiological symptoms of mineral deficiencies and excesses (4), and (iv) age-fertiliser effects upon physiology and chemistry of cane (3) have been presented in a series of earlier communications. These narrated the sequence of changes observed mostly under the conditions of pot culture. It is now desired to present in these pages, the variations induced in sugar-cane plant when nitrogen supply was made available at certain specified periods or at successive time intervals in the life cycle. A known quantity of nitrogen was applied to this crop at one or more growth stages in one or more instalments and the effects measured in terms of several developmental characters such as height, leaf number, leaf size, girth, length and number of internodes, yield and juice characters. Data pertaining to final stage of observation at or just before harvest are presented in the following pages.

Experimentation

The experiment was conducted under field conditions where the problem of nitrogen fertilisation is known to be of very great importance in the economics of sugar-cane production. Variety Co. 331 was grown for two consecutive seasons of 1939–40 and 1940–41 in a statistically laid out experiment with three randomised blocks of six treatments each. The details of the treatments are given below :—

Treatments :

(i) No Nitrogen (Control T_1)

(ii) Nitrogen in full dose at planting (T_2)

(iii) Nitrogen in three instalments (T_3)
- (a) 1/3 at planting
- (b) 1/3 at first earthing
- (c) 1/3 at final earthing

(iv) Nitrogen in four instalments (T_4)
- (a) 1/4 at planting
- (b) 1/4 six weeks later
- (c) 1/4 at final earthing
- (d) 1/4 dibbled after rains

(v) Nitrogen in three instalments (T_5)
- (a) 1/3 at planting
- (b) 1/3 at final earthing
- (c) 1/3 dibbled after rains

(vi) Nitrogen in two instalments (T_6)
- (a) 1/2 at planting
- (b) 1/2 dibbled after rains.

Basal dressing of 75 lbs each of P_2O_5 and K_2O was uniformly applied to each of the plots, the net size of which was maintained at 1/45 of an acre. Nitrogen was supplied to the plots at the rate of 150 lbs. of N per acre. Excepting treatment (i) where no nitrogen was added, all the other five treatments (T_2 to T_6) received the total quantity of nitrogen distributed over one or more stages of the life cycle as indicated above. The experiment was laid out in a well prepared sandy loam plot of known previous history. Sowing was done on 20th March, 1939, and the crop harvested on 24th March, 1940, in the first year of the investigation. In the second year, the respective dates for sowing and harvesting were 22nd March, 1940, and 2nd March, 1941.

Growth measurements were taken on six random stools from each plot ; data pertaining to leaf size and leaf number were obtained from the oldest tiller of the stool. Stem characters were also noted on this shoot. Chemical analysis of mature canes selected at random from different treatments was conducted at different stages. The procedure for estimating these juice characters has been described in an earlier communication (i). Summary tables of recorded observations towards the fag-end of growth are only given in the text.

TABLE I

Effect of time of application of nitrogen upon growth characters

Year		$T_{(i)}$	$T_{(ii)}$	$T_{(iii)}$	$T_{(iv)}$	$T_{(v)}$	$T_{(vi)}$	S.E. per plot	C.D. at 5%
					Mean height of cane (inches)				
1939 - 40		95.6	109.3	108.0	106.3	107.6	106.3	5.5	12.26
1940 - 41		116.4	117.6	124.8	121.3	123.6	124.8	1.19	2.65
					Mean girth of cane (inches)				
1939 - 40		3.1	3.26	3.20	3.23	3.20	3.26	0.21	0.46
1940 - 41		3.5	3.4	3.4	3.6	3.4	3.4	0.12	0.26
					Mean number of tillers per plant				
1939 - 40		5.0	4.0	6.3	6.6	6.3	6.6	0.8	1.78
1940 - 41		6.7	6.6	8.3	6.8	7.4	7.9	3.18	7.09
					Mean number of exposed internodes on shoot				
1940 - 41		20.0	21.1	20.9	22.0	20.3	20.9	2.96	6.60
					Mean size of longest internode on shoot (inches)				
1940 - 41		5.5	5.8	6.1	5.8	6.0	6.0	0.20	0.44
					Mean number of green leaves on shoot				
1940 - 41		7.1	7.3	6.6	7.4	6.5	6.8	0.37	0.82
					Mean length of fully expanded leaf on shoot (feet)				
1940 - 41		5.3	5.3	5.1	5.3	5.3	5.9	0.34	0.75
					Mean width of fully expanded leaf on shoot (inches)				
1940 - 41		2.0	2.2	2.2	2.3	2.2	2.1	0.3	0.669
					Yield of stripped cane per plot in mds.				
1939 - 40		16.3	18.0	16.0	18.0	15.3	18.6	1.06	1.938
1940 - 41		19.06	19.61	13.99	19.36	20.57	18.95	2.66	4.71
					Mean percentage of juice				
1939 - 40	T	43.6	44.6	52.6	53.3	53.3	54.0	4.5	10.03
	M	61.6	56.6	59.0	59.3	53.3	56.0	4.6	10.26
	B	51.6	57.0	64.0	56.3	60.0	64.0	3.9	8.697
1940 - 41	E	64.68	64.74	65.64	63.06	65.97	64.65	2.86	6.37
					°Brix in cane juice				
1939 - 40	T	18.3	18.6	18.3	18.6	18.6	18.3	0.87	1.94
	M	20.0	19.6	19.0	19.0	19.6	19.6	0.8	1.78
	B	20.0	19.6	19.0	19.0	20.0	19.6	0.85	1.89
1940 - 41	E	20.60	21.06	20.60	21.23	19.90	20.50	0.65	1.45
					Sucrose percentage in cane juice				
1939 - 40	T	12.3	12.0	12.0	12.3	11.6	12.6	1.4	3.12
	M	14.3	13.3	13.3	13.6	12.6	13.6	1.2	2.67
	B	15.3	14.3	14.0	14.3	14.3	14.3	1.2	2.67
1940 - 41	E	15.05	15.44	15.28	16.97	15.43	14.9	2.5	5.57
					Glucose percentage in cane juice				
1939 - 40	T	0.5	0.8	0.33	0.46	0.6	0.33	0.08	0.17
	M	0.36	0.66	0.36	0.4	0.46	0.33	0.15	0.33
	B	0.2	0.36	0.16	0.23	0.26	0.20	0.10	0.22
1940 - 41	E	0.97	0.98	1.10	1.55	1.05	1.06	0.48	1.07
					Purity coefficient of cane juice				
1939 - 40	T	66.6	62.0	65.3	65.6	60.0	68.3	6.7	14.94
	M	74.6	67.6	69.6	69.6	62.6	69.6	5.01	11.17
	B	76.0	72.6	73.0	75.0	71.3	72.6	4.09	9.12
1940 - 41	E	73.0	73.4	74.1	79.9	77.6	73.0	3.86	8.60

Note : T = Top of cane; M = Middle of cane; B = Bottom of cane; E = Entire cane.

Experimental Results

Nitrogen-fed plants, irrespective of the stage when this ingredient was made available, were found to be better in some respects than the control (no nitrogen) plants (Table I). On height of cane, this was very characteristically noted. Variation in the time of nitrogen application failed to bring about any significant change in the first year of the experiment. In the second, nitrogen applied in two instalments, half at planting and half dibbled after rains (T_6), proved to be as effective on height as nitrogen applied in three instalments, one-third at planting, one-third at first earthing and one-third at final earthing (T_3). In either of these treatments height of cane was significantly superior to most of the remaining treatments. On girth, tillering and number of mature internodes, nitrogen at different time intervals failed to bring about any significant effect. On size of the longest internode, some changes were found to take place in as much as nitrogen in three instalments (T_3) proved to be better than other treatments. Leaf characters in the second year were entirely unaffected by nitrogen supply at different stages. Yield of stripped cane also did not increase significantly over the control in many cases though a slight tendency to increased yield was noted under T_6 where nitrogen was applied in two instalments; this was particularly true for the first year of the experiment. Extraction percentage, °Brix, sucrose and purity coefficient, in the top, middle, or bottom of the cane, as also in the entire cane, were found to be unaffected by differential feeding with nitrogen at one or more of growth stages.

Conclusion

In the soil under investigation, nitrogen supply in carefully calibrated doses at different stages fails to introduce any marked increase in growth, vegetative vigour or juice quality of sugar-cane. Isolated instances of useful effects on height and size of the internode were however noted. It is suggested that variation in time of nitrogen application, as a means of further increasing the yield of sugar-cane, has no practical utility in the economics of sugar-cane production in these tracts. Application in full dose at planting would meet the end in view.

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REVIEW

Informe Preliminar sobre los taladradores de la cana de azucar, BY H. E. BOX, *Minister of Agriculture, Venezuela.*

An account, in Spanish but with an adequate English summary, of recent work on the *Diatraea* problem in Venezuela, where the author has not only spent the past year on a survey but has also observations from twenty years ago. Mr. Box has long experience with *Diatraea*, having studied the systematics of the genus some years ago, and has here given a comprehensive list of the food-plants of the species occurring in Venezuela. The economic position of each species, both with regard to geographical distribution and ages of cane attacked are considered. He then mentions possible methods of control, and comes to the conclusion that biological control of the pest, coupled with regulated cultural practices, is the only method offering chances of success in Venezuela. He suggests that the Amazon fly, *Metagonistylum minense* Tns., and later the Cuban fly, *Lixophaga diatraeae* Tns., should be introduced, and that further search should be made for efficient parasites of *D. canella*. There is an extensive bibliography dealing with the *Diatraea* problem in general, and a number of illustrations of the various species, their damage and parasites. These do, however, suffer rather from the method of printing and the quality of paper used in the publications.

F. J. S.

A LABORATORY COLOUR TEST FOR THE DIAGNOSIS OF SWOLLEN SHOOT OF THEOBROMA CACAO

BY

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Introduction

The accurate diagnosis of the swollen shoot virus diseases of cacao in the field is sometimes difficult for the inexperienced observer, and a simple positive test for infection might increase the efficiency of control by roguing (Posnette, 1943 ; Anon, 1945). A colour test for the infection of peach trees with the virus causing phony disease was described by Hutchins (1933). This test, which depends on the accelerated colouration of sections of infected root immersed in acidified methyl alcohol, was applied by Posnette to cacao stems, since the virus is systemic in cacao, whereas in the Phony disease of peach it is largely confined to the roots. Instead of the infected material developing purplish spots as occurred with the peach, he found a general production of a magenta colour in the wood, and this colouration was frequently accelerated by the presence of the virus. These preliminary trials were sufficiently promising for the writer to proceed with the investigation in an attempt to produce a simple test for swollen shoot.

Method

Transverse sections are cut about 0.2 mm. thick, and immediately immersed singly in a few ccs. of acidified methyl alcohol contained in a small covered porcelain evaporating basin. The methyl alcohol, which must be anhydrous, is acidified with concentrated hydrochloric acid at the rate of 2 to 5 drops per 100 ccs. The amount of acid is increased with lower temperatures so that the colour will appear in between 2 and 7 minutes.

There is considerable variation in the rate of colouration between comparable sections from the same stem. Differences in thickness and water content cause some variation, but since longitudinal sections develop transverse striations due to differing colour reactions at different points on the stem, some variation between transverse sections would appear uncontrollable. It is therefore necessary to use statistical analysis of a number of observations to distinguish between this inherent variation and differences caused by virus infection. Stems of 3/8 to ½ inch diameter are selected from the suspected tree and from a healthy tree. The stems selected should be as similar as possible in water content and morphology. For each comparison, four pairs of sections, each pair consisting of one from the healthy and one from the suspected stem, are cut, alternating the order of the two stems. The first appearance of the magenta colouration is recorded only to the nearest minute because of the difficulty of judging when the colour first becomes visible. Any sections which take longer than 10 minutes to colour are recorded as having taken that time.

For each test, these comparisons are repeated four times so that a total of 16 sections of suspected stem are compared with the same number of healthy sections. The colouring times are summed separately for each comparison of four pairs of observations, and the significance of the means of these totals is estimated, using the " t " test at the 5% level of significance. An example of a test and the results obtained is given in Table 1. In this typical result, the mean difference exceeds the significant difference indicating that the infected tree colours significantly more rapidly.

TABLE 1

	Colouration Times in Minutes				Total Time	Mean Diff.	Significant Difference
	1st Series	2nd Series	3rd Series	4th Series			
Healthy tree	3	2	3	3			
	2	2	2	4			
	5	4	1	2			
	2	1	3	4			
	12	9	9	13	43		
Tree infected with Virus 1.A	1	1	1	2			
	1	1	2	1			
	2	1	2	1		5.75	3.64
	1	1	1	1			
	5	4	6	5	20		

Results

1. *Virus 1.A* *

The tests made with virus 1.A are summarised in Table 2 in two sets. The 29 stems from various infected trees coloured significantly more rapidly than the healthy controls in the majority of tests, particularly in the second series when more experience had been gained. 39 comparisons between healthy trees did not yield a single significant difference; hence a significant difference definitely indicates the presence of virus. However, since infected trees do not always produce a significant result, a negative test cannot be relied upon to demonstrate the absence of virus, although several tests using different healthy controls will usually reveal the virus if it is present.

2. *Other Cacao Viruses*

Virus 1.B, which is regarded as a mild form of virus 1.A (Crowdy and Posnette, 1947) has produced results similar but somewhat less consistent than virus 1.A (Table 2). Virus 1.C (Kpeve), which is probably outside the strict swollen shoot complex, producing an entirely different symptom pattern in the leaf and no stem swellings, actually depresses the rate of colouration.

Viruses 1.F (Wiawso) and 1.G (Dochi) both gave positive reactions less consistently than viruses 1.A and 1.B. Viruses 1.E (Pameng) and 1.D (Nkawkaw) have been insufficiently investigated for conclusions to be drawn. It would appear that their reaction is certainly less than that of virus 1.A, but three of the trees had probably not been infected long enough with virus 1.D to give the reaction, and the one significant result was obtained from stems brought from the original outbreak near Nkawkaw.

* For a discussion of the nomenclature of cacao viruses and description of those mentioned here, see Posnette (1947).

3. *Further Observations on the Colour Test Using Virus 1.A*

During the preliminary work on this test, rather variable results were obtained, and tests were therefore made to determine whether there was any seasonal effect on the reaction. Three pairs of healthy and infected trees were tested at weekly intervals from December to February, and for the remainder of the year at monthly intervals. The results were consistently significant and positive with the exception of one tree in June and July. However, this tree was by then practically dead and had to be replaced, and the only other exceptions were the replacement pair and one other pair each of which gave one insignificant result. It was concluded that there is no correlation between the colour test and season.

Several comparisons were made between swellings and the unswollen parts of infected stems, but no difference was detected. Sections cut at intervals along a stem revealed no differences apart from the sappy wood near the growing point which coloured more slowly. A control test was made to ensure that the more rapid colouring of infected material was not due to it being drier or more woody. No significant differences were detected between younger, more sappy stems and older, drier stems when both were healthy.

There is a period of about three months between the infection of a tree with virus 1.A and the appearance of the symptoms. It would be useful if the colour test could be used to reveal infected trees during this incubation period. However, preliminary tests indicated that the colour reaction was only produced after the visible symptoms.

Another use of the test might be to determine the presence of swollen shoot in material sent from a distance. It is often more convenient to send stems wrapped in damp moss

TABLE 2

Summary of Results of the Colour Test Applied to Various Cacao Viruses

Virus and Origin	No. of Tests	Positive Tests		Negative Tests	
		No. sig.	No. not sig.	No. not sig.	No. sig.
1.A (New Juaben)	17	10	6	1	0
	12	11	1	0	0
Healthy controls	39	0	39	—	—
1.B (Bisa)	13	8	5	0	0
1.C (Kpeve)	13	0	3	7	3
1.F (Wiawso)	12	4	5	3	0
1.G (Dochi)	10	5	4	1	0
1.D (Nkawkaw)	5	1	2	2	0
1.E (Pameng)	3	0	2	1	0

Note: "Positive Test" means that the infected material stained more rapidly, "Negative Test", that it stained more slowly than the uninfected control.

than to press leaves sufficiently well for the patterns of leaf symptoms to remain visible. Experiments showed that stems stored in this manner, similar to budwood, can be kept for three weeks, and at any time tested against either fresh or similarly stored healthy stems with the same results as if fresh material was used.

Discussion

While this colour test is not sufficiently positive to form a simple field test for swollen shoot, it is of some value as a laboratory test, which can yield reliable results provided the necessary precautions are taken. In practice, it is useful for the recognition of the most virulent virus in material cut from the trees, and sent some distance to the laboratory. Under these conditions, leaf specimens do not usually travel well unless carefully dried, but it is a simple matter to wrap a few stems in damp moss. When tested on arrival, a single significant acceleration of colouring over the healthy control indicates infection, but because non-significant results do not necessarily mean absence of infection, it is recommended that several suspected stems are compared with different healthy trees. If then all the tests are not significant, there is a strong probability that there is no infection with a virus which gives the reaction.

The colour test may prove of value in helping to elucidate the relationships of the various strains of the swollen shoot complex. It is interesting that this test confirms the visual symptoms and immunisation results in separating virus 1.C from viruses 1.A and 1.B.

The colouration of the cocoa stems appears to be due to the production of phloroglucinol in the wood under the influence of the anhydrous methyl alcohol. This phloroglucinol condenses with the furfural present to form a reddish colour in the same manner as in the phloroglucinol test for liquified tissue. It is not known which stage is accelerated by the virus.

Summary

1. Swollen shoot of cacao can be demonstrated by the more rapid colouring of sections of stems immersed in anhydrous acidified methyl alcohol.

2. The increased rate of colouring is small, and owing to the uncontrolled variation it is necessary to make a number of observations and assess the results statistically. In practice, sixteen pairs of observations on suspected and healthy stems are made and the significance of the results is estimated by a simple application of the " t " test.

3. The test can be applied to stems stored under moist conditions for three weeks.

4. Different cacao viruses react differently. The most consistent results are given by the virulent virus 1.A, while less virulent viruses like 1.B and 1.F give a weaker positive reaction. The probably unrelated virus 1.C produces a weak negative reaction, the virus depressing the rate of colouration.

Acknowledgements

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THE MANGANESE CONTENT OF LEAF AND INFLORESCENCE TISSUE IN RELATION TO THE "UNKNOWN DISEASE" OF THE COCONUT PALM IN JAMACICA

BY

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Introduction

The disease of coconuts occurring in the Western Parishes of Jamaica has been described by Martyn (1945), Bain (1940) and Leach (1946). Leach, mainly on growth records concludes that "the disease may be associated with a facultative root parasite but that soil conditions are the main controlling factor in as much as they affect the nutrient status of the palms". A palm shewing a sudden checking of the growth rate of its leaves and/or nuts succumbs to the disease. Seasonal conditions which favour active growth tend to encourage the disease. "The more luxuriantly palms grow and the better yielding capacity they have, the more susceptible they appear to the disease". *Leach also points out, however, that the palms on a variety of soil types are affected.*

On the assumption that the disease might be a minor element deficiency or toxicity, Leach took a very limited number of leaf samples and submitted them for analysis. The samples were obtained from nine trees on Round Hill Estate in Saint James and when grouped into "healthy", "supposedly healthy from diseased areas", and "diseased", a graduation in the manganese status of the dry matter was obtained, suggesting that the disease was due to manganese deficiency. There was no apparent association between the disease and the calcium, magnesium, potassium, phosphorus, iron or boron content of leaf tissue. This paper describes further work on the manganese status of coconut palm tissue, carried out with the object of investigating the relationship, if any, between the incidence of the "Unknown Disease" and the uptake of manganese.

Symptoms

Previous descriptions of the diseased condition of palms in the West of Jamaica have not drawn attention to the fact that there are two very distinct and separate manifestations as shown by the symptoms occurring in the unopened spathes. In one instance the unopened inflorescence turns brown and rots (tissue breakdown), the discoloration commences at the tip of the male inflorescence and works backwards. Closer examination reveals that the breakdown and the brown colouring travel backwards along the branches of the inflorescence (rachis), often, apparently, passing by male florets and leaving them temporarily unaffected. It enters the male florets *via* the pedicel and *invades the bracts first.* Often the bracts are a full brown colour, yet the stamens inside retain their normal appearance, *i.e.*, they are unaffected by the rot. In extreme cases the stamens become eventually affected and breakdown. The colour invades the female flowers *via* their pedicels also, but only in very advanced cases of inflorescence breakdown. This type of diseased condition is characterised by a general wetness of the breaking down tissues and often by a stench. The pedicels are weakened and even before the spathe opens the male florets are shed, leaving characteristic bare, brown, inflorescence brushes. No case was observed where the florets had opened in the unopened spathe.

In the other kind, the symptoms are typically the opposite. Upon opening an unopened spathe, it is seen that the terminal male florets are being shed but the main branches of the inflorescence supporting them are *not* discoloured; they are normal; pedicels are also normal in appearance, but brittle; the anthers, however, are discoloured, the extremities being bluish grey and the pollen has been or is being shed. In extreme cases, the anthers are curled and distorted and the stamens proper tend to be translucent due to slight tissue breakdown. Even in unopened male florets the anthers are already discoloured and the pollen free. The affected inflorescence appears excessively dry. The condition works back from the tips of the inflorescence branches but no symptoms have so far been associated with the female flowers. When the spathe opens, most of the male flowers are already shed leaving the branches bare but *not* discoloured. The latter wither as they would normally. No brown colouring has been associated with these symptoms. Palms shewing the symptoms are sterile but appear to be otherwise unaffected.

It is assumed that the former is associated with Leach's so-called "Unknown Disease" and for reference purposes in this paper these symptoms are referred to as symptoms "A". The second condition is not confined to the area being ravaged by the "Unknown Disease",

though it is very common throughout that area ; it has been observed in the Llanrumney area of Saint Mary and in the Duckenfield area of Saint Thomas and in this paper is referred to as symptoms " B ". In both these areas and in Saint James and Hanover, the palms grow on dark brown or black, crumby soils of high alkalinities overlying soft limestone, where the condition is an important factor reducing yields. Further observattions may prove that the intensity of the condition varies with season as many of the palms involved shew a periodicity in their bearing and barrenness, *e.g.*, the coconut palms at Llanrumney in Saint Mary.

The Palms

The present distribution of " Unknown " diseased palms shews that palms of all ages are attacked, and in all conditions of vigour. On areas of Tryall, Cousins Cove, Sandy Bay and Lucea, palms bearing sixty nuts and more per annum, and forty years old have *suddenly* succumbed to the disease. On the other hand, equally old palms, small and slow-growing, which bear no more than two mature nuts per " bunch " have been killed, and recently, palms, three to five years old planted as supplies in fields where formerly vigorous palms of up to forty years old were wiped out by the disease, are themselves being killed. These supplies may be interplanted with sugar-cane, or bananas, or may be growing in pastures which are not cultivated. Some even occupy seashore sand bars bare of any subsidiary economic crop.

The Soils

Most of the coconuts affected by the disease in the past six years have occupied alkaline, sedentary or alluvial soils derived from soft limestone (of the Montpelier Series of Sawkins), soft recent coast limestone, or from calcareous, soft, carbonaceous shales of the Richmond Series. At Green Island, Mosquito Cove and between Montego Bay and Reading, the soils are generally alkaline, slightly calcareous alluvia derived from mixed geological formations, including the Trappean Series of Sawkins, which contains purple shales, high in manganese content. In Eastern Saint James between Little River and Falmouth, palms have been killed on shallow, brown and red terra rossa and a similar, but small area exists east of Green Island. No evidence has been obtained to date that palms growing on acid land have been affected, though it is probable that this may have happened on parts of Bogue estate near Montego Bay. The disease occurs under conditions of free drainage as well as in areas suffering from varying degrees of impeded drainage. It also occurs on coral sand bars on the seashore.

It is a well-known fact that soil reactions (acidity or alkalinity) govern, to a major degree, the availability of soil manganese to plants. Leeper (1934 and 1935) found that manganese deficiency was confined to soils of pH 6.7 and over and occurred especially on heavily-limed land. The pHs met with in most of the disease areas are all high, being nearer 8 than 7 so that an acute manganese deficiency might be expected. But on grounds of alkalinity and calcareousness, manganese deficiencies should be equally acute in other areas of Jamaica, including important coconut areas, *e.g.*, on soils derived from soft limestone, such as occur in the coastal area of Trelawny, Saint Ann, Saint Mary, Portland and Saint Thomas, and, if as Leach contends, luxuriance of growth and production are conducive to the disease, manganese deficiency symptoms in coconuts should be considerably more acute in Saint Ann, Saint Mary, Portland and Saint Thomas, than they are in Hanover.

As far as the author is aware, no data exist on the manganese status of coconuts. A comparison of the manganese status of palms growing on all the main neutral or alkaline coconut soils and the soils of Saint James and Hanover in particular, should establish whether the disease is correlated with low managanese uptake.

Samples Used

Leaf and spathe samples were collected. Where palms were flowering, the oldest unopened spathe (*i.e.*, the spathe which would open next) was sampled, together with the leaf subtending that spathe. The leaf was sampled by stripping twenty leaflets from one side of the midrib, midway between the base and the tip of the leaf. In the laboratory, the spathe was opened and the inflorescence branches cut below the male flowers and above the female flowers, the two portions dried and analysed separately. Where palms were so young as not to have flowered, the fifth fully-opened leaf, counting outwards from the middle of the crown, was sampled. The plant tissue material was dried in an oven, passed through a " C and N " laboratory mill, and digested by the wet, perchloric acid method, the manganese present being estimated colorimetrically using the periodate oxidation method.

Discussion

The manganese contents of the dry matter of the leaf, the male flowers and the female flowers, fluctuate together and in general are of the following relative magnitudes :—

Leaf	Male flowers	Female flowers
100	48 $\pm$ 28	37 $\pm$ 11

If manganese deficiency is the cause of, or a factor predisposing palms to the real cause of the disease, palms affected by the disease should shew lower manganese contents than those surviving, and those palms in a "disease area" which have yet to suffer from the disease should have lower manganese contents than palms in areas where the disease is unknown.

The following table summarises the data obtained :—

The Distribution of Palms According to the Manganese Status of their Leaf Dry Matter

p.p.m. Mn. in dry matter	0–9	10–19	20–29	30–39	40–49	50–59	60–
Diseased palms	—	1	6	3	2	2	3
Palms unaffected to date but growing in disease area	—	14	13	18	8	3	7
Palms growing outside the diseased area	1	13	24	7	3	1	18

It is very evident that no relationship exists between the manganese status of the palm leaf tissue and the incidence of the "Unknown Disease". The range of manganese contents of leaf material outside the "disease belt" is not noticeably different from that in palms of the "disease belt". Furthermore, not only do palms of very high manganese status die of the "unknown disease" but palms with manganese contents of only 10 to 20 parts per million dry matter in the leaf, and 4 to 5 parts per million dry matter in the inflorescence bear heavily and are, apparently, quite healthy. This is not very surprising when compared with some other crops, *e.g.*, Eureka lemon leaves shewing no symptoms of manganese deficiency contain 10.7 – 17.0 parts manganese per million dry matter and rough lemon leaves only 5.6 to 8.6 parts per million dry matter (Haas, 1932).

In August, 1946, forty-five young palms, three to four years old (not yet bearing) which had been planted as supplies in fields where the "Unknown Disease" had completely wiped out bearing palms, were selected. Thirty were underplanted with sugar cane at Haughton Court on a badly-drained soil; five were in a mixed peasant cultivation on free draining alluvium at Bowden Hill, Lucea Harbour, and ten were on a sand bar at West Tryall. At the time of sampling in August, six palms with the following manganese status were diseased – 20, 25, 18, 22, 78, 38 parts manganese per million leaf dry matter. Between August and December, a further six palms succumbed to the disease and these palms contained 27, 32, 21, 53, 42, 17 parts manganese per million leaf dry matter. The observations are not very advanced, but indicate that to date the order in which "supply" palms die of the disease, bears no relationship to manganese status of their leaf tissues. These observations are being continued.

It is not possible from the data to decide at what level of manganese in leaves, coconuts suffer manganese deficiency. The limits are certainly below 20 parts per million dry matter and may well be below 10.

It is interesting that such variation in manganese status was obtained from highly alkaline, calcareous soils and that generally, the figures were not much lower. The very high figures encountered in Trelawny were obtained from land which had rusty mottling and surface "shot" – *gley* formation near the surface, and was rich in humus. The high figures for Junor Cove and Haughton Court were obtained on highly alkaline, calcareous soils, rich in organic matter, but under swamp conditions. With the exception of number 87, 88, 89, 90 on Round Hill and numbers 6 and 11 at Clifton Hill, the remainder were in old pastures, pastures established after bananas, in sugar-cane or on waste land – areas where the soil contained variable, but generally high accumulations of organic matter. Furthermore, most of the soils were heavy clays shewing field evidence of fluctuating conditions of oxidation and reduction. It seems probable, therefore, that, where the availability of soil manganese is concerned, a high organic matter content and/or the presence of fluctuating conditions of soil aereation may well offset the fixation influence of high lime status and alkalinity. Similar effects have been demonstrated by Piper (1931).

The data have dealt with manganese. It may be suggested that the disease is due to the deficiency of some other element. If, however,

the palms are suffering from a nutritional deficiency, growth and fruiting should tend to slow up in accordance with some function of the magnitude of the deficiency, and either the soils must have been deficient from the commencement of coconut growing, or the supplies of the deficient element must have been suffering progressive depletion over a period of time. The behaviour of the disease does not conform to the expected reaction of plants to an existing deficiency or to one which is becoming more and more acute. The heavy-yielding, quick-growing palms which shew all the signs of being on very fertile land succumb to a sudden breakdown, whereas the slower-growing palms which shew all the signs of being on land where growth and fruiting are being held in check by soil factors, survive longer (*but ultimately succumb to the disease also*). The plant-food supplies of soils, especially humus-rich clay soils, do not give out suddenly. Yet, coconuts which have borne heavily for thirty years (at Tryall) without any sign of the disease are all suddenly dying and so also are the supplies. One may well ask how it is that palms, all having fruited heavily for the last thirty years and growing in Flint River alluvium suddenly succumb to the disease, whereas palms of a similar age, fruiting equally heavily and growing in the same alluvium, but upstream and separated by half a mile of limestone gorge, are completely healthy today.

The cause is unlikely to be associated with soil aeration or soil oxidation-reduction conditions since the disease occurs in swamps, on sand bars and on free draining hillside soils. That it should be associated with limestone soils is improbable for large areas of similar soils occur outside the " disease belt ".

In order to dispose of the minor-element-deficiency hypothesis, minor-element solid-injection experiments are to be commenced. Preliminary work indicates that coconut palms with well-developed trunks can stand the following quantities of chemicals distributed between twelve, one-half inch diameter, three-inch deep auger borings spread evenly around the circumference of the trunk and sealed with hardwood bungs – boric acid 21 grams per palm ; copper sulphate 10 grams per palm ; ferrous sulphate 100 grams per palm ; manganese sulphate 100 grams per palm and zinc sulphate 100 grams per palm. The investigations will be carried out on palms with formed trunks growing in fields through which the disease is actively spreading.

Summary

Detailed descriptions have been given of the inflorescence symptoms of the " unknown disease " and of another condition which is prevalent, not only in the " disease area ", but also outside the " disease area " and is the cause of much sterility in coconuts.

Data have been presented shewing the manganese status of the dry matter of coconut leaves and unopened inflorescences for diseased palms and " healthy " palms in the " disease area " and for palms outside the " disease area ". The data prove that there is no obvious relationship between the incidence of disease and the manganese content of palm leaf tissue. Furthermore, it is unlikely that any palms examined were suffering from an acute manganese deficiency. The limit of adequacy for manganese content, in parts per million leaf dry matter, in coconuts, is probably not above 10 and certainly not above 20.

On highly alkaline calcareous clay soils the presence of much organic matter and/or fluctuating conditions of soil aeration and reduction, are probably factors causing an adequate uptake of manganese by coconuts.

The symptoms of the disease are not such as would normally be expected from a nutritional deficiency, but on the assumption that the disease may still be due to a minor element deficiency, future lines of investigation are outlined.

Acknowledgment

The analytical work was undertaken by the junior staff of the Agricultural Chemistry Division ; to them my thanks are due.

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NOTES ON THE ROOT SYSTEM OF IMMORTELLE (ERYTHRINA GLAUCA)

BY

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Immortelle is exclusively planted as a shade tree on the clay soils of our Surinam empoldered plantations. Other trees were tried from time to time, but none could compete with Immortelle as to general suitability.

Before 1820, cacao and coffee were planted without shade on freshly empoldered rich pegasse land with a high humus content. In such fields, cacao production remained as high as 400 kg per acre for 40 years. But after this time the soil became exhausted, the humus reserve disappeared and the mineral content available for cacao was reduced. Therefore the cacao production declined rapidly.

In about 1820 planters realised that by growing Immortelle trees, old exhausted plantations could be replanted with permanent success, though the cacao production in the shaded fields was at a lower level (200 — 250 kg per acre). From this time onward cacao, as well as coffee, was planted under shade trees.

Immortelle is indigenous in our fresh water marshes inside the brackish coastbelt. South of Nickerie and near the Cottica River pure stands of this tree are found on places where the land is deeply flooded during the greater part of the year.

Most trees adapted to grow in marshes have some kind of pneumatophores to absorb oxygen and supply it to the roots in the non-aerated soil, by forming stilt roots or knee roots. In its natural habitat, Immortelle shows no such formation, but it possesses another type of root that possibly may function in the same manner.

Long flexible lateral roots grow from the trunk into the swamp water. The side branches form thick mats of fibrous roots floating just below the surface of the water. They show a fair quantity of big bacterial nodules. No air channels are found in these roots, as might be expected. There are, however, in the inner cortex many big cells filled with an oily substance that colours brown with Sudan III. This oil may help the roots to float. In the primary floating roots of nursery plants the cortex consists of a loose spongy parenchyma without oil cells. If these root mats function as pneumatophores, the oxygen apparently has to be carried along the phloem to the deeper roots in a compound form, for instance, as substances like peroxydase or oxygenase.

In low insufficiently drained clay fields the soil is partially covered by a flat, thin mat of fibrous roots if it is protected by a thick layer of decaying leaves. Such mats can easily be peeled off. The same mats were found in Trinidad by V. I. Mulloon * on heavy, impervious clay covered by decaying leaves. In these superficial roots no oil cells are present. In better drained fields no mats are formed, but even here some superficial branches of fibrous roots can be found if covered by sufficient leaf litter.

Immortelle trees growing along the channels of our empoldered plantations produce plenty of roots floating in the water along the borders of the channels. They are most conspicuous during the dry season, when the water level is one to two feet lower than in the rainy season. The root mats can be seen at this time lying on the slope below the high water mark.

One can easily understand now why a tree that grows wild in our clay marshes proves to be especially well adapted as a shade tree in our empoldered plantations which were reclaimed from the same type of marshes.

Years ago we were informed that Immortelle roots were still found below a depth of seven feet in the stiff, bluish clay. This is important because such a deeply penetrating root system must be able to carry more mineral substances *via* the leaves to the surface of the soil, than a shallow one. The roots of cacao and coffee, at least the laterals, are restricted to the humic top soil. Deep-rooted shade trees therefore enlarge indirectly the available soil area for such shallow-rooted trees.

With regard to this earlier information, I made a study of the root system of three Immortelle trees in our experimental garden. The first one was a 25 year old tree in a well-drained field. At a distance of five feet from the trunk a straight trench 4 feet wide and 40 feet in length was dug. Here the humic topsoil had a depth of 12 inches. Below it there was a 2-feet thick layer of a light grey clay. Below 3 feet the clay was very sticky and more bluish. On the wall at the side of the trunk 21% of the roots were found in the 12 inches of humic topsoil. In the upper half of the grey clay (12 — 24 inches) 58%, and in the lower half (24 — 36 inches)

* *Trop. Agric.* XX, 11, p. 216.

21% of the total amount of roots were counted. In the sticky clay, below 3 feet, not a single root could be detected. On the opposite wall of the trench 7% of the roots were found in the topsoil, 76% between 12 and 24 inches and 17% at 24 — 36 inches. One of the roots in the topsoil of the ridge of the bed reached as far as 60 feet from the trunk. There was no taproot. In the grey clay I never found bacterial nodules nor root hairs at the end of the fibrous roots.

The second, an Immortelle about 40 years old, grew on an insufficiently drained site. The trench was dug at a distance of 3 feet from the trunk. The humic topsoil varied in depth from 7 — 12 inches. Below it was a grey, wet and sticky clay. Here 65% of the roots were found in the first foot and 35% in the second.

The third, a tree about 40 years old, stood along a channel on a badly drained place. Along the channel, however, there was a 1½ feet high ridge built up some time ago when the channel was dug. The Immortelle grew on this ridge. Here 47% of the roots were found in the first foot, 41% in the second, 10% in the third and 2% just below 3 feet. In the badly drained soil next to the ridge 84% of the less numerous roots were counted in the first foot and 16% in the second. Evidently the Immortelle roots preferred the better drained soil of the ridge.

Unfortunately, we had no opportunity to dig an Immortelle in its natural habitat in deeply flooded marshes with extensive floating root mats. Only at the end of an exceptionally severe and long dry season this might be carried out with success. It is expected that the roots do not penetrate in such places much deeper than one foot into the soil. This is confirmed by Ir. J. de Kraker, who often found uprooted trees in the Immortelle forest on the upper Cottica River. The fallen trees form watershoots all along the trunk. This is the reason why full-grown Immortelles often grow in the marshes in rows close together.

The first Immortelle tree had 318 kg of fresh leaves (73 kg dry). About 18 Immortelles are planted per acre. Supposing that every tree was the same size as the one dug, 5,700 kg leaves would be shed every dry season by 25 year old Immortelles. Our tree, however, grew along the edge of a field, so that an average of not more than 5,000 kg leaves would be shed every year. Together with the cacao leaves, a very substantial manuring with organic matter is carried out in this way. Only a fraction of the mineral content of the total leaf litter comes from the subsoil, possibly one-fourth. A part of the minerals is retained in the trunks and branches. It is not released before the field is cleared and the wood decayed.

To compare the root system of Immortelle with that of cacao and coffee, a cacao and two Liberia coffee trees were dug. The 23 year old cacao tree was a neglected one with three stems and four watershoots. It grew on clay near a sandreef. The clay was partially mixed with sand. Every stem had its own tap root with short laterals. These tap roots were 3 feet long. The watershoots had separate tap roots, 2 — 2½ feet long. The common laterals were spreading exclusively in the one foot humic topsoil. At ten places, however, the thicker laterals had adventitious tap roots or turned self straight down.

The two 25 and 40 years old coffee trees that grew near the two first dug Immortelles had a very dense superficial root system penetrating scarcely deeper than 6 inches into the topsoil. The main lateral roots concentrated in the upper 2 inches. Both trees had no tap root at all.

Though coffee has a more shallow root system than cacao, it recovers more quickly than cacao from an abnormally severe drought. But the humus content of the topsoil is high and evaporation from the soil surface is limited during the dry season by an adequate covering of leaf litter, even cacao for more than 200 years had no trouble from abnormally severe droughts. The drought of 1926 had a disastrous effect only on the neglected cacao shaded with much too old and weak Immortelle trees.

Only vigorous Immortelles not over 30 — 35 years old are able to produce sufficient additional leaf litter to ensure an adequate insolating cover and a topsoil of good crumbly structure that prevents cracking of the stiff clay and retains sufficient moisture even during abnormally severe droughts.

It is shown above that the roots of Immortelle trees penetrate deeper in well drained clay soils than in badly drained, enabling them to grow more vigorously and to bring more minerals from the subsoil to the surface. They also produce a bigger quantity of humus.

Deep drainage and young vigorous Immortelles are therefore the most important requisites for the successful cultivation of cacao on the stiff Surinam clay soils.

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Root system of a 3-stemed cacao tree with adventitious tap roots.

Root system of a Liberia coffee tree on clay soil.

Immortelle nursery plant, 4 months old, growing in clay covered with 3 inches of water. Note floating roots.

Root system of an Immortelle tree.

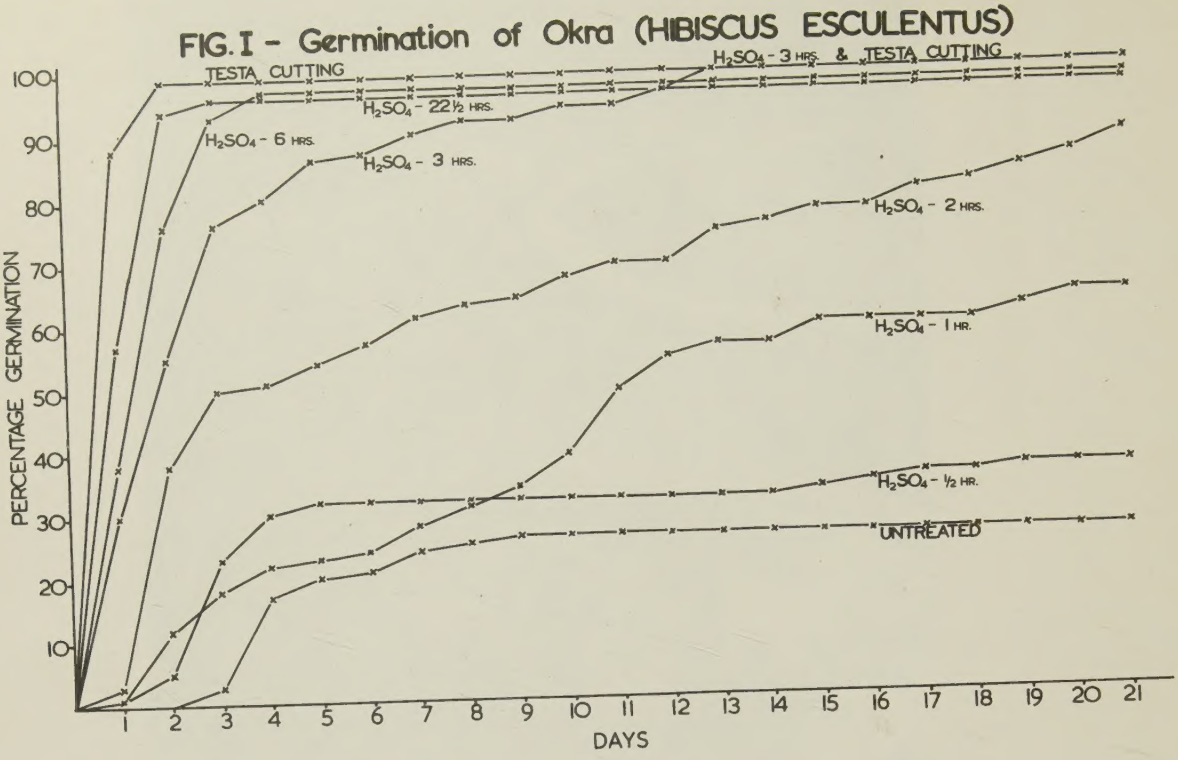
FIG. I - Germination of Okra (HIBISCUS ESCULENTUS)
PERCENTAGE GERMINATION
DAYS
TESTA CUTTING
H2SO4 - 3 HRS. & TESTA CUTTING
H2SO4 - 22½ HRS.
H2SO4 - 6 HRS.
H2SO4 - 3 HRS.
H2SO4 - 2 HRS.
H2SO4 - 1 HR.
H2SO4 - ½ HR.
UNTREATED

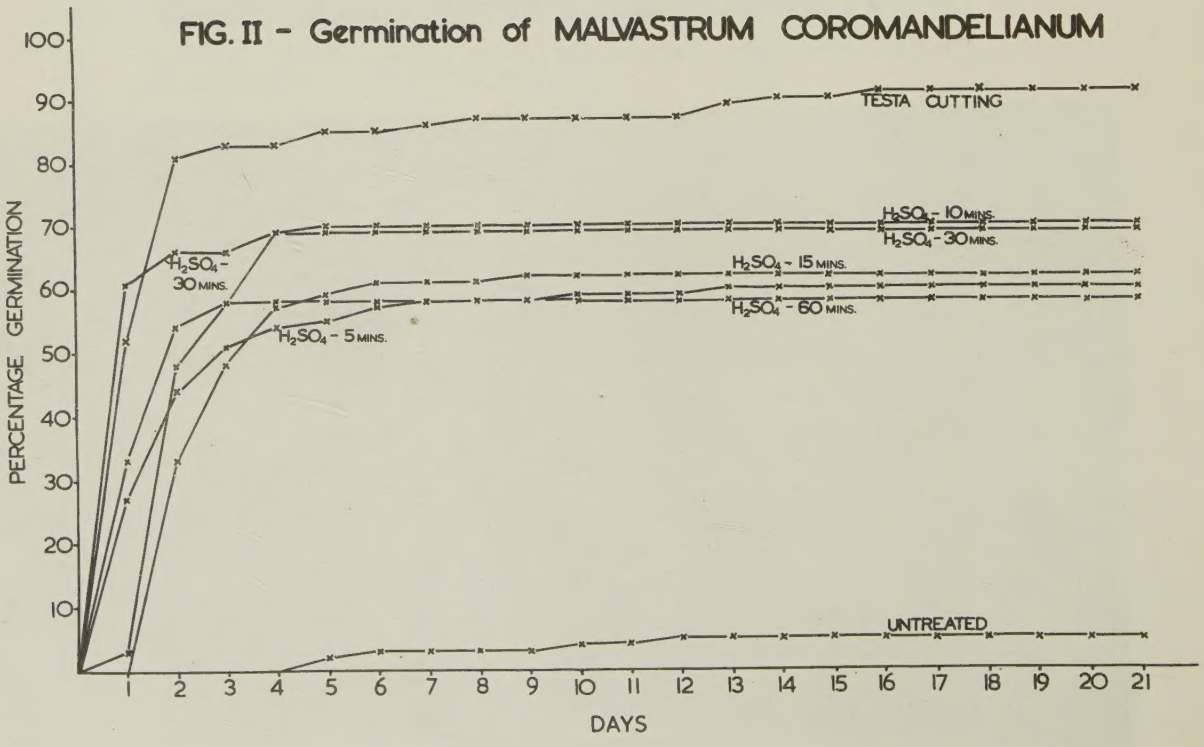
FIG. II - Germination of MALVASTRUM COROMANDELIANUM
PERCENTAGE GERMINATION
DAYS
TESTA CUTTING
H2SO4 - 10 MINS.
H2SO4 - 30 MINS.
H2SO4 - 30 MINS.
H2SO4 - 15 MINS.
H2SO4 - 60 MINS.
H2SO4 - 5 MINS.
UNTREATED

THE GERMINATION OF MALVACEOUS SEEDS

BY

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Introduction

During experiments with members of the Malvaceae in Trinidad (Owen, 1946) germination was often poor and occurred irregularly over several weeks. Experiments described below, with four of these species, showed that the testas inhibit germination. There are many examples in the literature of seeds showing delayed or erratic germination which can sometimes be improved by increasing the permeability of the testa. This may be effected by treatment with concentrated sulphuric acid, or by scarification or fracture of the seed-coat. Such behaviour amongst tropical crop plants has been reported for tea (Tubbs, 1932), rubber (Tincker, 1943) and, in Malvaceae, for cotton (Brown, 1933) and *Urena lobata* (Horn & Colon, 1943).

Materials and Methods

The species used were *Malachra alceifolia* Jacq., *Malvastrum coromandelianum* (L.) Garcke, *Sida rhombifolia* L. and okra (*Hibiscus esculentus* L.) ; the last-named is commonly cultivated, and the other species are common indigenous members of the Trinidad flora. Seeds collected in April, 1945, were stored in a desiccator until the tests were carried out in the following August and September. The experiments involved two basic treatments : (1) seeds were immersed for varying periods in concentrated sulphuric acid, washed thoroughly and sown on damp filter paper in Petri dishes ; (2) small pieces of testa were cut off (avoiding damage to the embryo) and the seeds sown as before. In all tests 100 seeds were subjected to each treatment and 100 untreated seeds sown as controls. The carpels were removed from seeds of the three wild schizocarpic species to facilitate cutting of the testa, but control seeds and those treated with acid were sown enclosed in the carpels, preliminary tests having shown germination to be unaffected by their presence. The duration of each test was three weeks, germinated seeds being removed and counted daily.

Results of Germination Tests

Total germination percentages are given in Table I. while Figs. I and II show, in addition, the effect of the treatments on germination rate in *Hibiscus* and *Malvastrum*. Untreated seeds germinated poorly, especially those of *Malvastrum* and *Sida*. In all species, germination was greatly improved and accelerated by either treatment, but cutting was superior to the sulphuric acid method. The optimum period of immersion for the latter varied : for *Malachra* it was 15—30 minutes, for *Malvastrum* 10—30 minutes and for *Sida* 30—60 minutes, or possibly more ; okra germinated best after 3 hours' immersion, but there was no appreciable falling off even after 22½ hours.

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TABLE I

Effect of Testa Cutting and Acid Treatment on Seed Germination in Four Species of Malvaceae

	PERCENTAGE SEED GERMINATION										
	Untreated control	Period of immersion in sulphuric acid									Testa cut
		5 min.	10 min.	15 min.	30 min.	1 hr.	2 hr.	3 hr.	6 hr.	22½ hr.	
Malachra	43	36	48	85	82	78	—	—	—	—	99
Malvastrum	5	60	70	62	69	58	—	—	—	—	91
Sida	5	18	19	39	56	60	—	—	—	—	82
Hibiscus	26	—	—	—	36	63	88	99	97	96	99

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CONTROL OF THE BAMBOO POWDER-POST BEETLE IN PUERTO RICO

BY

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Over a period of about 40 years, some 35 species and varieties of bamboo have been introduced and established in Puerto Rico by the Federal Experiment Station at Mayaguez. Today, many of these species have shown themselves to be well adapted to local conditions, and interest in the timber value of some of them has led to their establishment in potentially commercial quantities in various parts of the island. However, the main obstacle to the full utilisation of many species has been the serious infestation of the harvested culms by the widely distributed bamboo powder-post beetle *(Dinoderus minutus* (L.))

Although no one bamboo species has yet been found to be entirely immune, systematic testing has shown that some possess considerable natural resistance to this most troublesome and damaging pest. Of those studied thus far, the first-year growth of eight species and one variety has been found to be from 90 to 99 per cent resistant to attack in comparison with the common, highly susceptible *Bambusa vulgaris* Schrad. Much of this resistance was associated with lack of starch in the wood, and, where little starch was present, resistance was correlated with low moisture content and high specific gravity (*8*). Such non-resistant species as *B. vulgaris* and a tall-growing, thin-walled variety of *B. arundinacea* react to the iodine spot test for starch more strongly than any others. Although much variation has been found, usually the upper part of the culm was more resistant than the lower and the older the culm before being harvested, the greater was its total resistance to this pest (*9*). Where this was not the case, as in *B. tuldoides* Munro and a thin-walled variety of *B. tulda* Roxb., 1-year-old culms had as much resistance as 5-year culms, whereas those of intermediate age had somewhat less (*9, 11*). In *Sinocalamus oldhami* (Munro) McClure, another timber species, 1-year-old culms were slightly more resistant than 5-year culms (*12*).

The use of resistant species and varieties, of course, would be an ideal solution to the problem of controlling the bamboo powder-post beetle. Indeed, some have been found sufficiently resistant to make them attractive commercially, and, with due attention to curing and inspection to eliminate infested pieces, a few species have been utilised for some years with rarely, if any, infestation in the finished product. However, in one of these, the thin-walled variety of *Bambusa tulda* that has been in use the longest, the loss by culling on account of the beetle has occasionally been as high as 25 per cent of the culms harvested.

The best of artificial methods to increase resistance to beetle attack either have been too cumbersome or employed materials too hazardous to human health, or they have damaged the wood or adversely affected its quality for many uses (*3, pp. 32, 37, 39; 5, p. 35; 6, p. 116; 7, p. 82*). All have tended to increase the cost of marketing this fast-growing and versatile forest product and none has been entirely satisfactory for all purposes. External applications of creosote and similar materials changed the colour of the wood to an undesirable brown; Paris green made the wood too poisonous to handle, and so did successive dips in sodium arsenite and copper sulphate. Copper sulphate as a dip or injected into the culm by the sap-stream or stepping method changed the colour of the wood to a light green, not too objectionable for some uses but definitely so for others, and in addition it corroded hardware in contact with the wood. Floating the culms on water made the wood light and brittle; submerging them in water increased sap stain. Recently, tests of the effect of "bakelite-forcing" were conducted in cooperation with the Puerto Rico Development Company (*11, p. 36*). While this impregnation of the wood with bakelite did not entirely close the pores of the wood or materially change its reaction to iodine, it did harden the wood and imparted to it other commercially desirable qualities. Under the most severe conditions of infestation pieces so treated remained immune to the beetle, while untreated wood of the same species and age was heavily attacked. This method would seem mostly applicable in the manufacture of small articles or some kinds of furniture.

The growth regulating substances, 2, 4-dichlorophenoxyacetic acid, indolebutyric acid, and indoleacetic acid, have been tried for their effect on the starch content of the wood, but none was found to alter perceptibly this important factor in beetle control. The injection of 2 per cent hydrochloric acid into the culm by the sap-stream method was tried for the same purpose but with little effect (*7, p. 79*).

Among the least cumbersome methods of control that have given good results have been